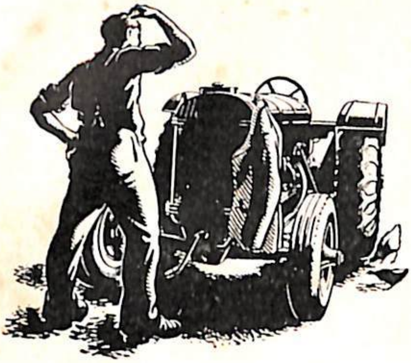
FARM MECHANIZATION HANDBOOK

10/48



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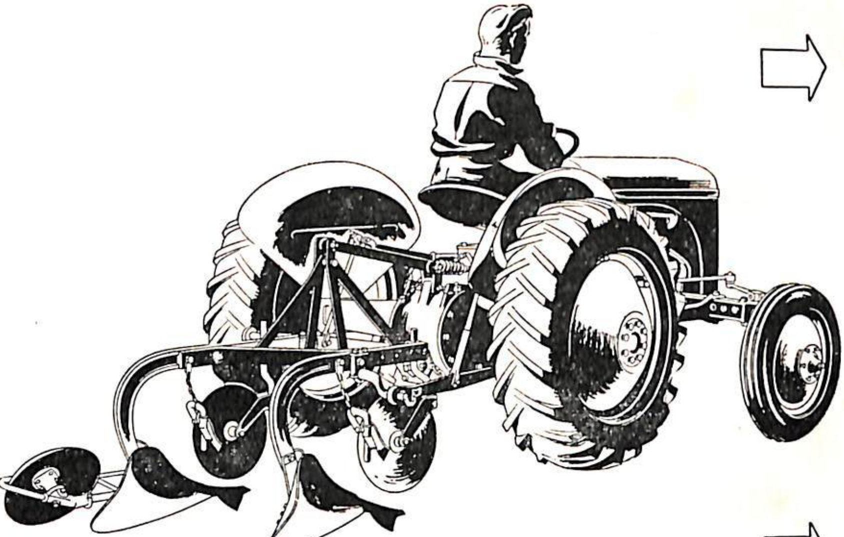

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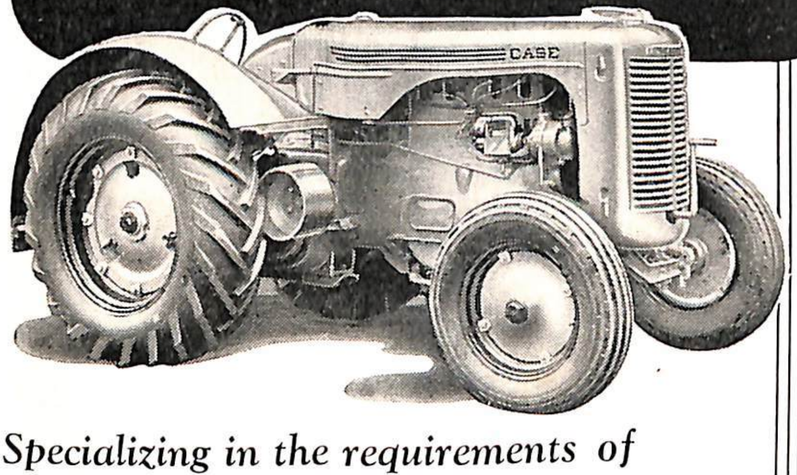

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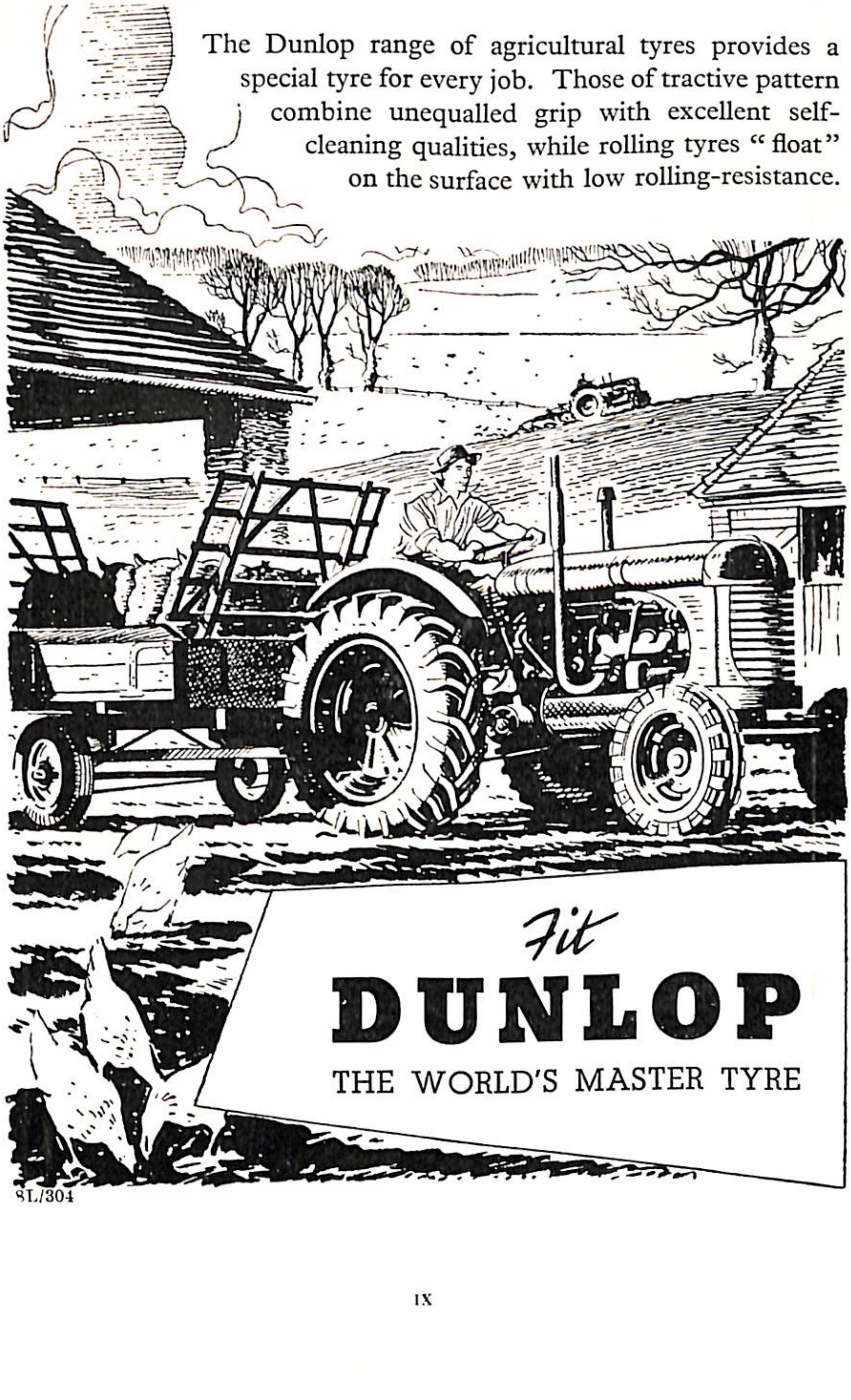

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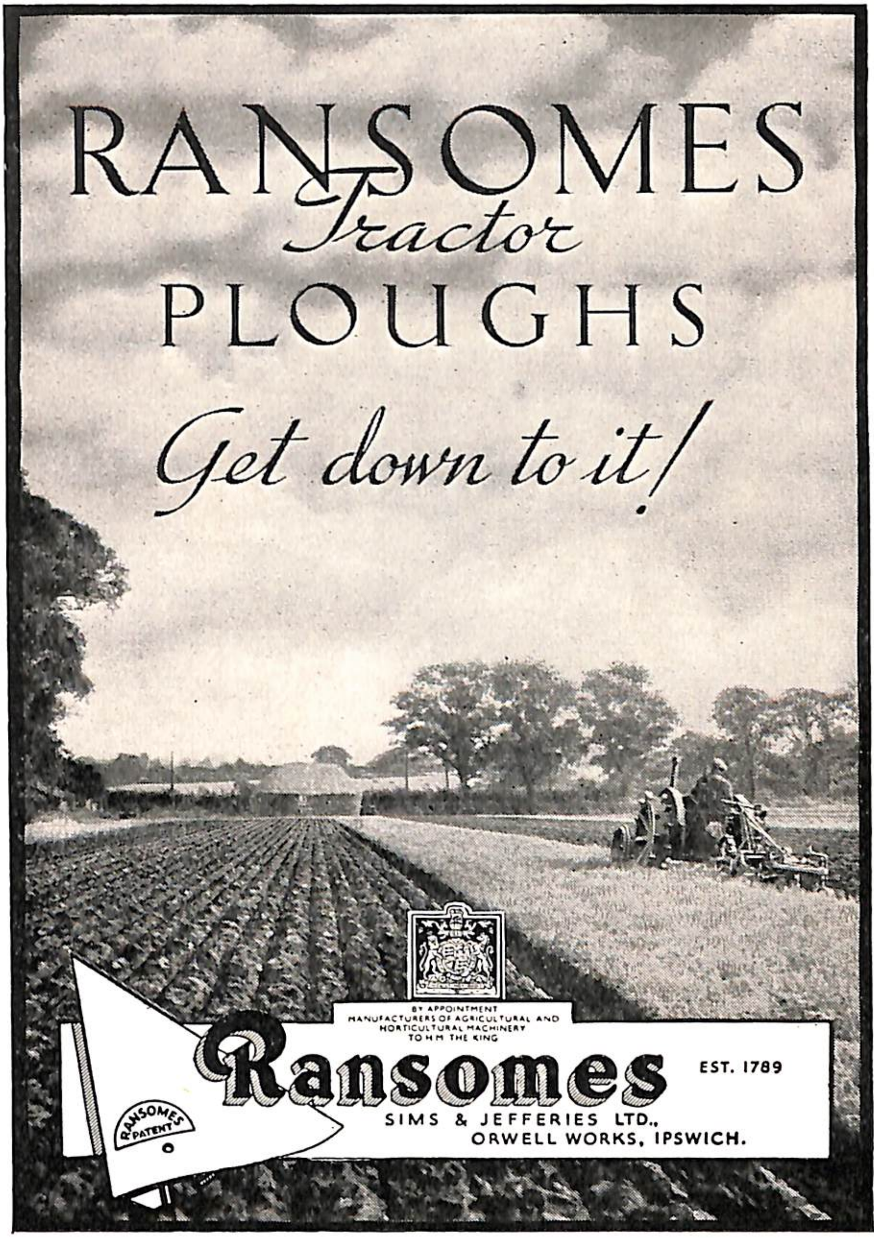

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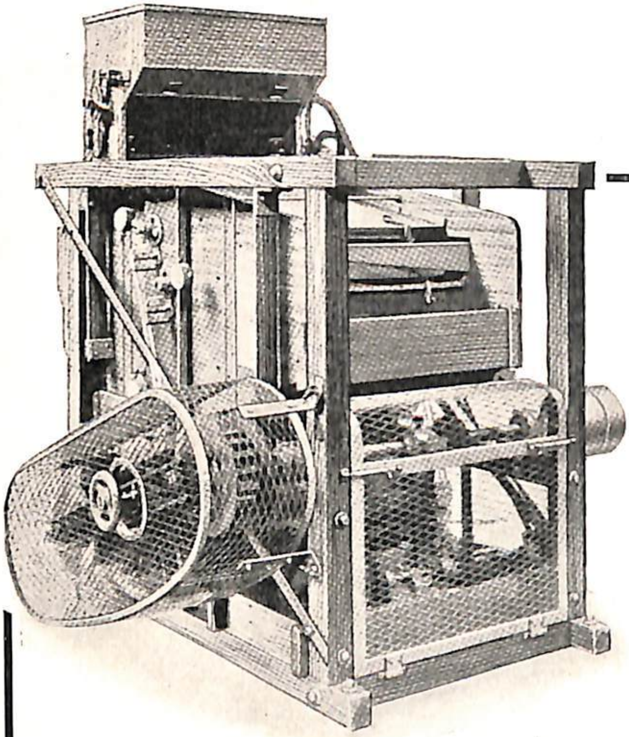

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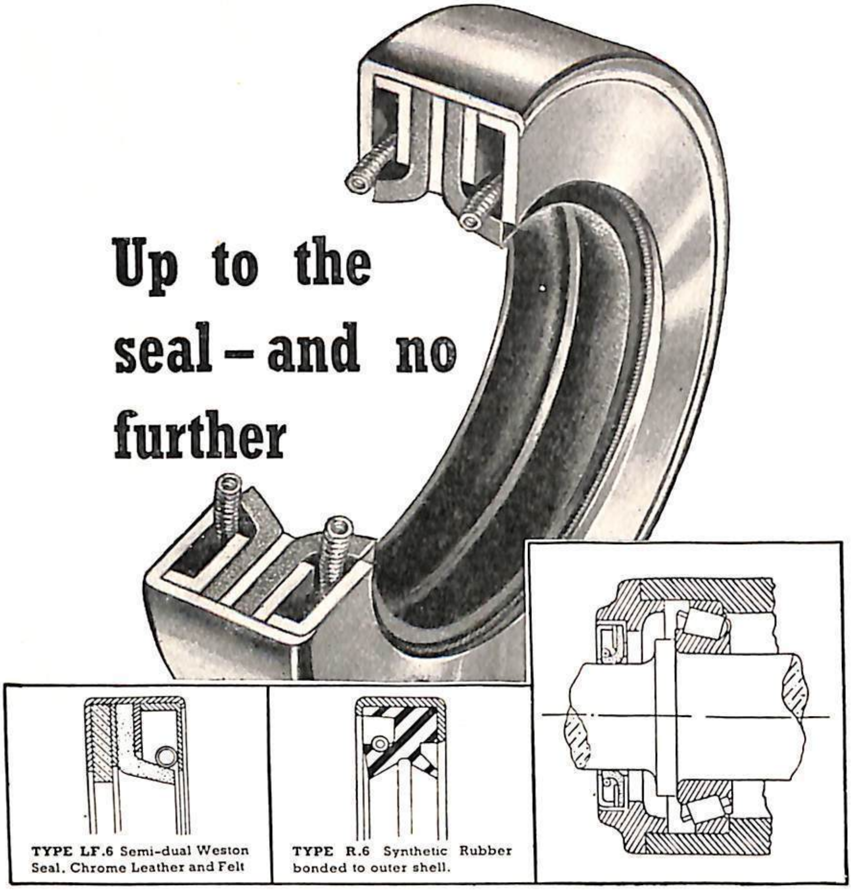
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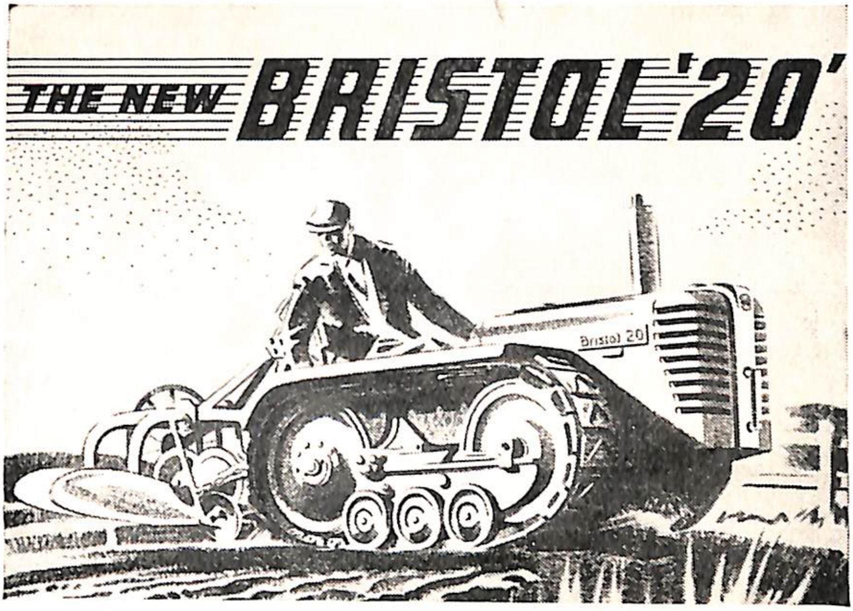

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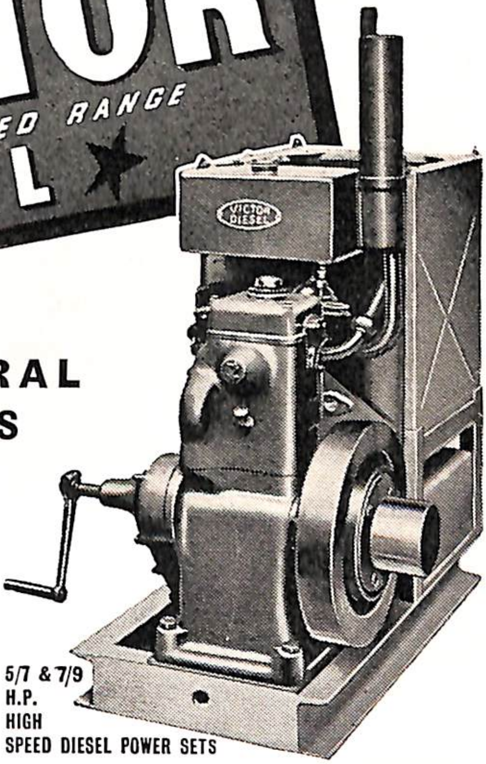

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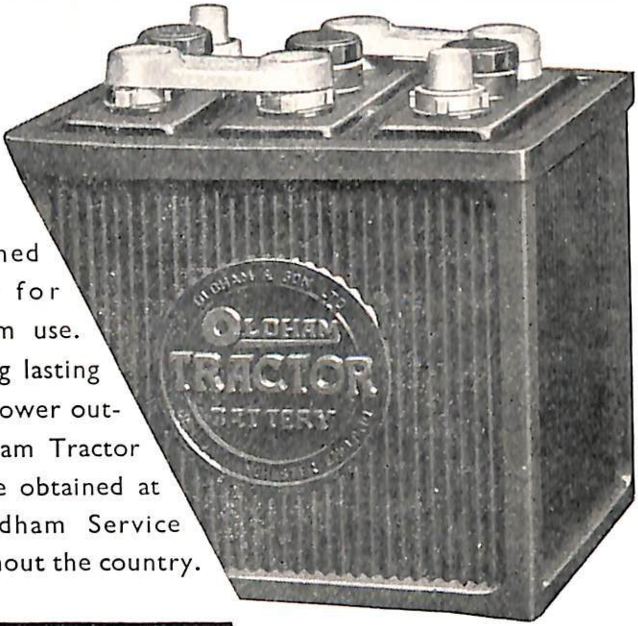

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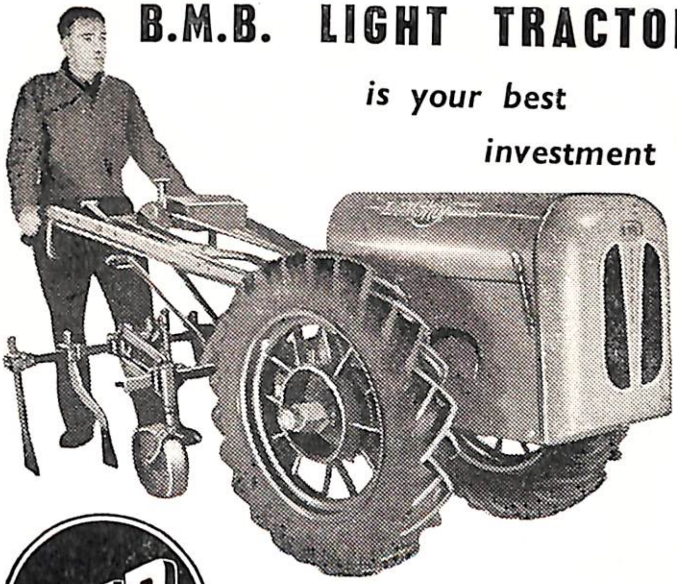

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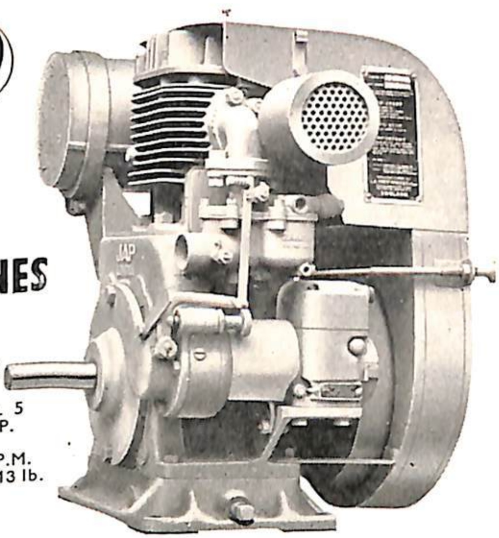

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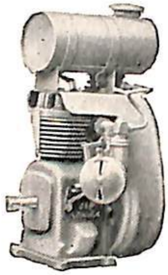

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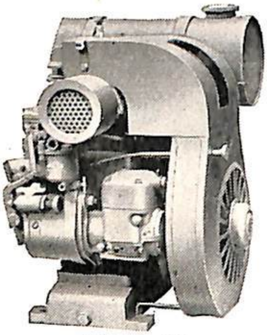

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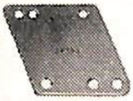		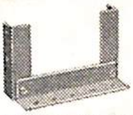		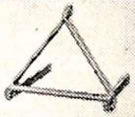
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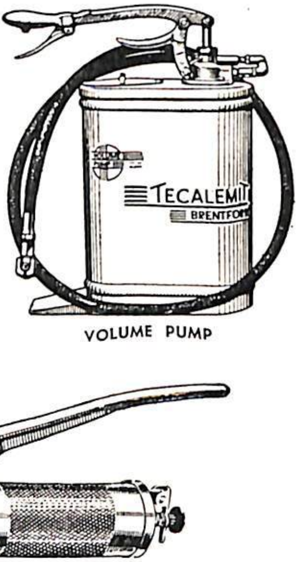

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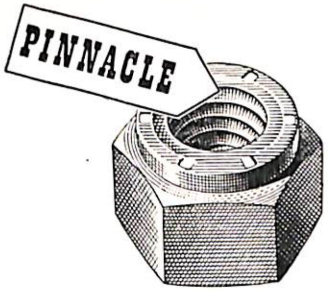

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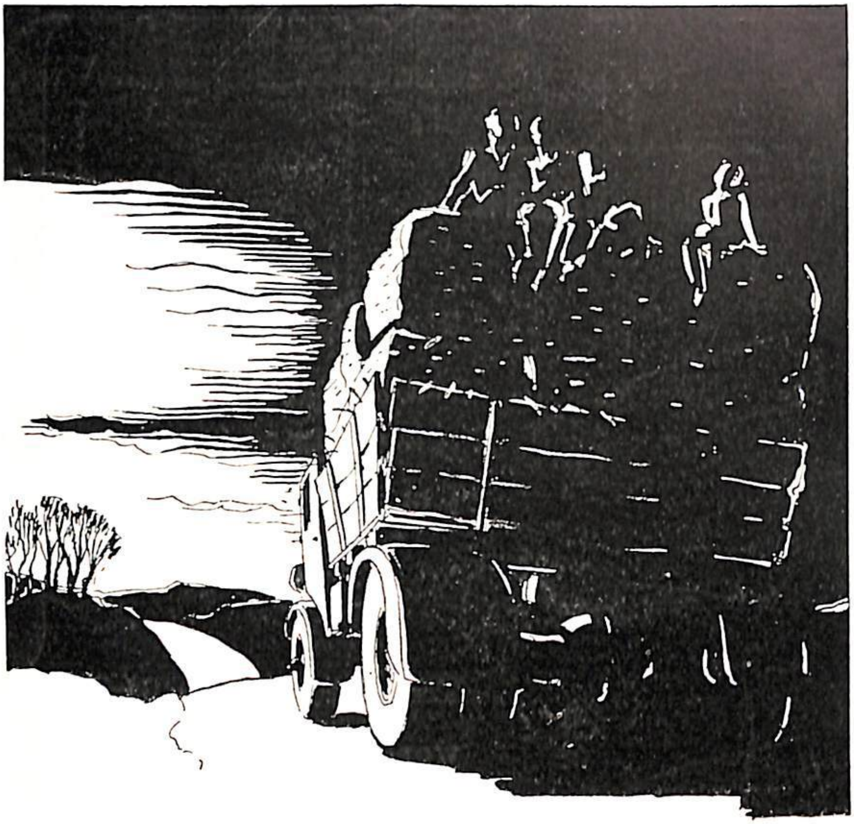

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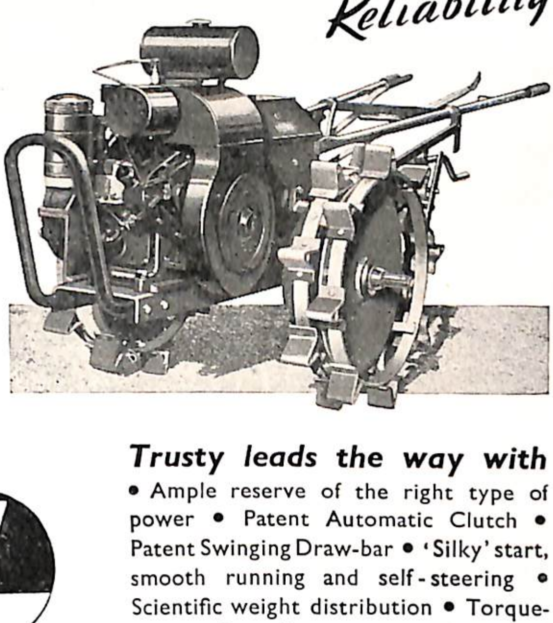

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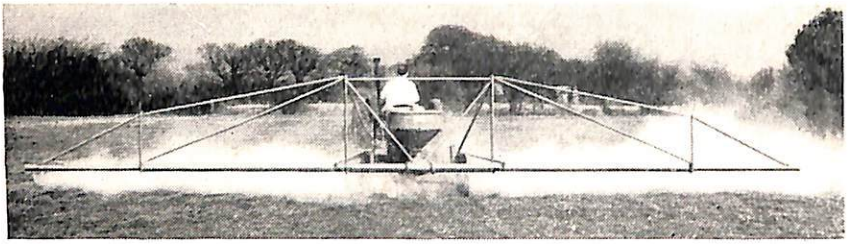

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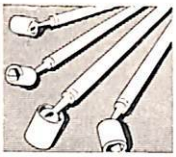

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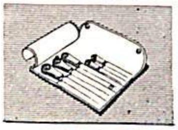

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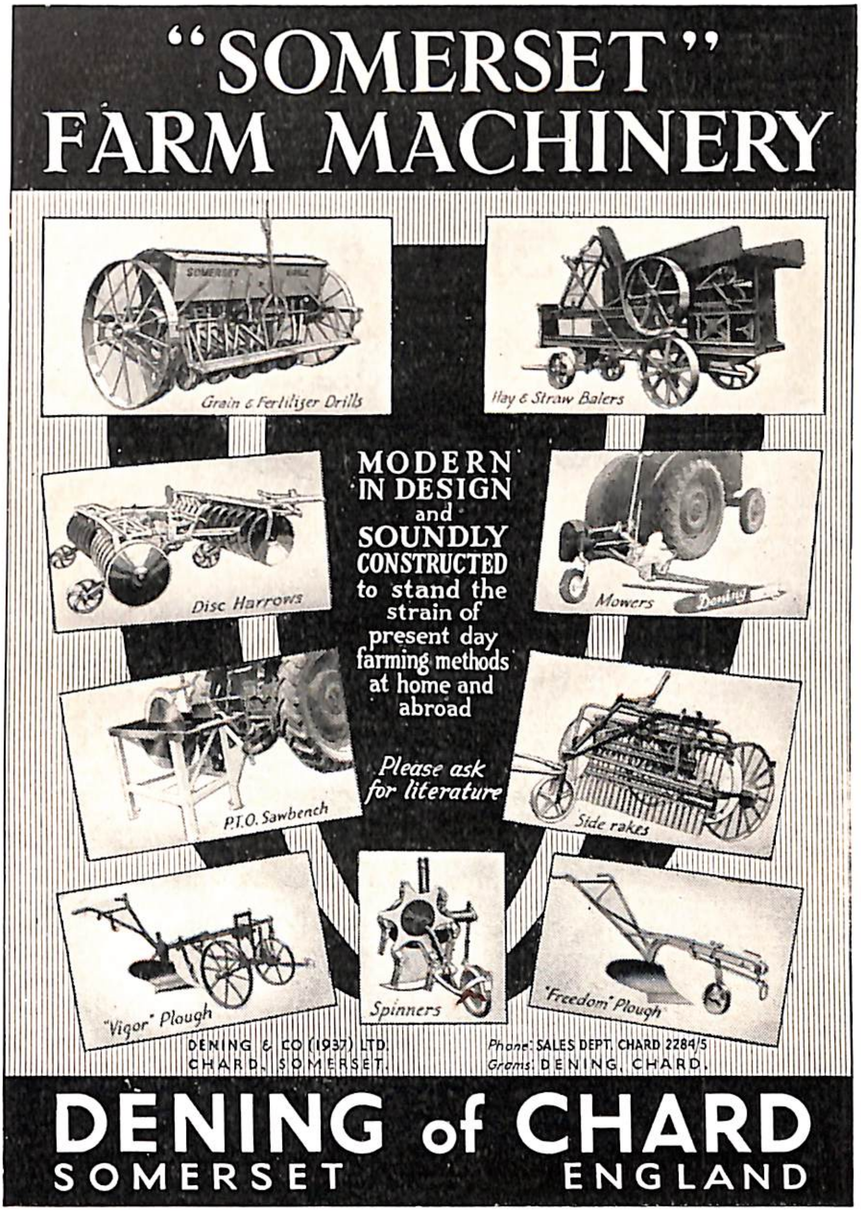

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FARM MECHANIZATION HANDBOOK

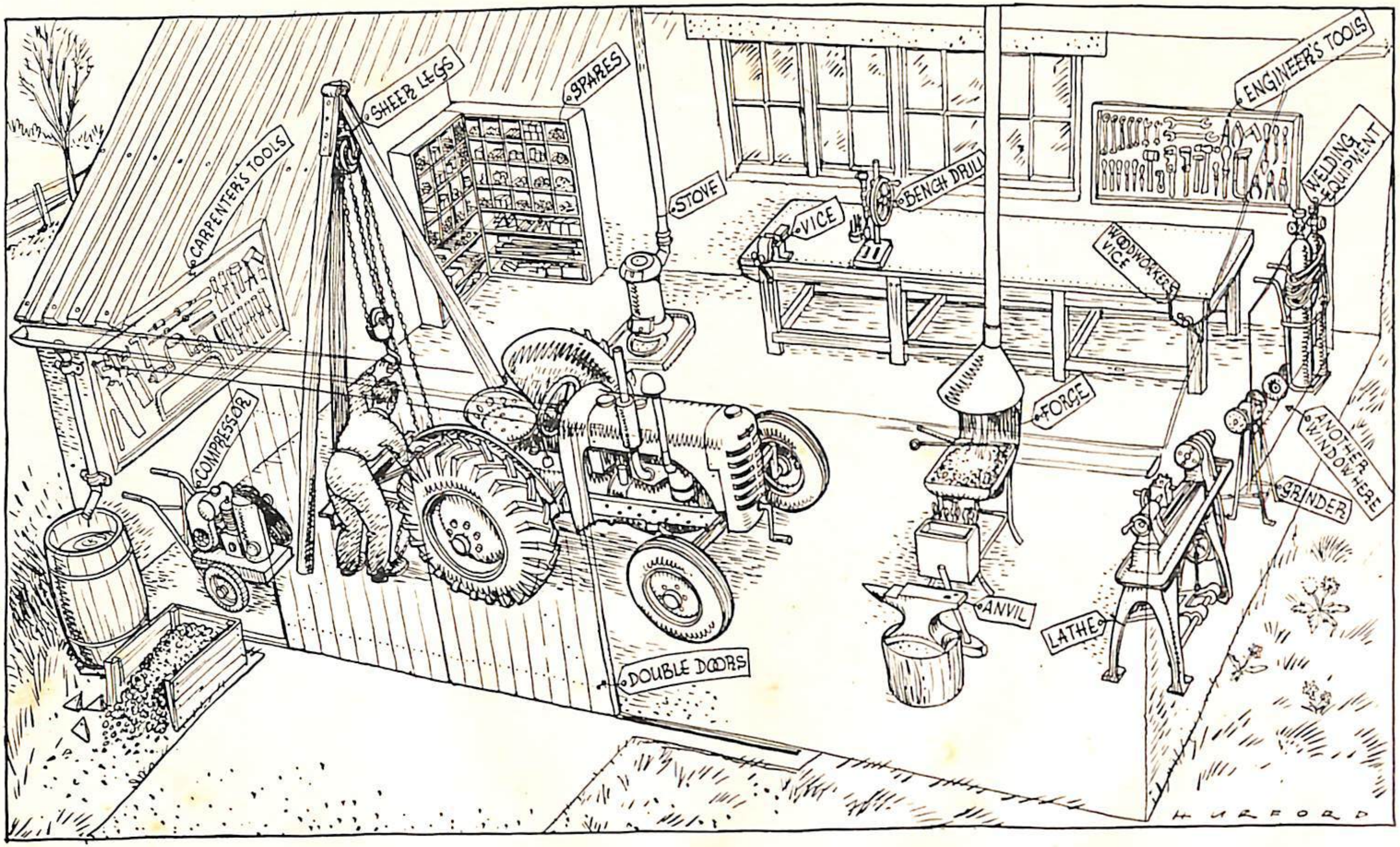

Fig. 1. *Suggested layout and equipment for a farm workshop.*

FARM MECHANIZATION HANDBOOK

A Manual of the Repair and Maintenance of Farm Machinery

by

P. A. REYNOLDS

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INTRODUCTION

WITH the mechanization of farms, it is becoming essential for a greater percentage of farm workers to have some knowledge of mechanics, particularly whilst deliveries of new machines are uncertain and spare parts and full repair facilities restricted.

This book is, therefore, designed to give a general working guide to the care and maintenance and general operation of most common types of machine found on the modern farm. No attempt has been made to go into the particular adjustments or repairs of specialized machinery such as binders, combines, threshing machines, etc., although internal combustion engines are dealt with exhaustively. The principles contained in many of the chapters on workshop practice will enable an intelligent mechanic to keep most equipment running in times of emergency and to overcome many of the everyday problems met on the farm.

NOTE

The following pull-out, diagrammatic illustrations of tractors will be found at the end of this book.

THE ALLIS-CHALMERS MODEL "B"
THE BRISTOL TRACTOR
THE DAVID BROWN TRACTOR
THE CATERPILLAR D2 TRACTOR
THE FARMALL MODEL "H"
THE FERGUSON TRACTOR
THE FIELD MARSHALL DIESEL TRACTOR
THE FORDSON MAJOR
THE TRUSTY TRACTOR

1

THE FARM WORKSHOP

MUCH of the machinery used on farms is simple and easily understood, but the tendency of recent years is towards the use of appliances which combine the work of three, or even four, old-type machines, and which may even utilize engineering principles new to the farmer. The combine harvester and the hydraulic mechanism now fitted to some tractors are examples.

The time is thus approaching when the services of a trained engineer are needed on all highly mechanized farms. Indeed, some have already anticipated this and employ a man whose sole task is to keep machinery and implements always ready for use. Other farmers send their repair work to agricultural implement repairers. Still more, however, try themselves to carry out repair jobs. There is little doubt that an enormous amount of time and money are saved if the work can be done without sending it away, but it cannot be denied that general on-the-spot repair work has been greatly hampered by the lack of proper facilities. Unless a man has a workshop containing an adequate range of tools and appliances, the quality of his work is bound to suffer.

The Building

At the moment difficulties of building a new workshop lead to consideration of the possibility of making do with an old barn or a lean-to shed. Such buildings, when converted, can be made to provide reasonable facilities, even if this only means a place in which to keep a bench and tools.

Undoubtedly the ideal is to have a building large enough to house all the repair equipment, the stock of spare parts, and still leave room to take a tractor or whatever other machine requires attention. It must, of course, first be made reasonably weatherproof. A damp workshop is highly conducive to the formation of rust, and good work demands tools that are in first-class condition. Next in importance to a sound roof is the floor, which must be level and hard. Earth floors are certainly warmer than concrete, but they should be avoided if possible on account of the grit and abrasive matter which cannot be prevented from coming into contact with machinery. A concrete floor is not, it is true, entirely free from dust, but at least it does provide a sure foundation for jacks and other lifting appliances which may otherwise topple over or sink and cause injury to personnel and further damage to the machinery.

Make sure, too, that the doors are sufficiently wide and high to accommodate the largest of the mobile equipment, and bear in mind the advantage of doors both sides of the building, so that a tractor can draw in, leave its load behind for repair and drive out the other side.

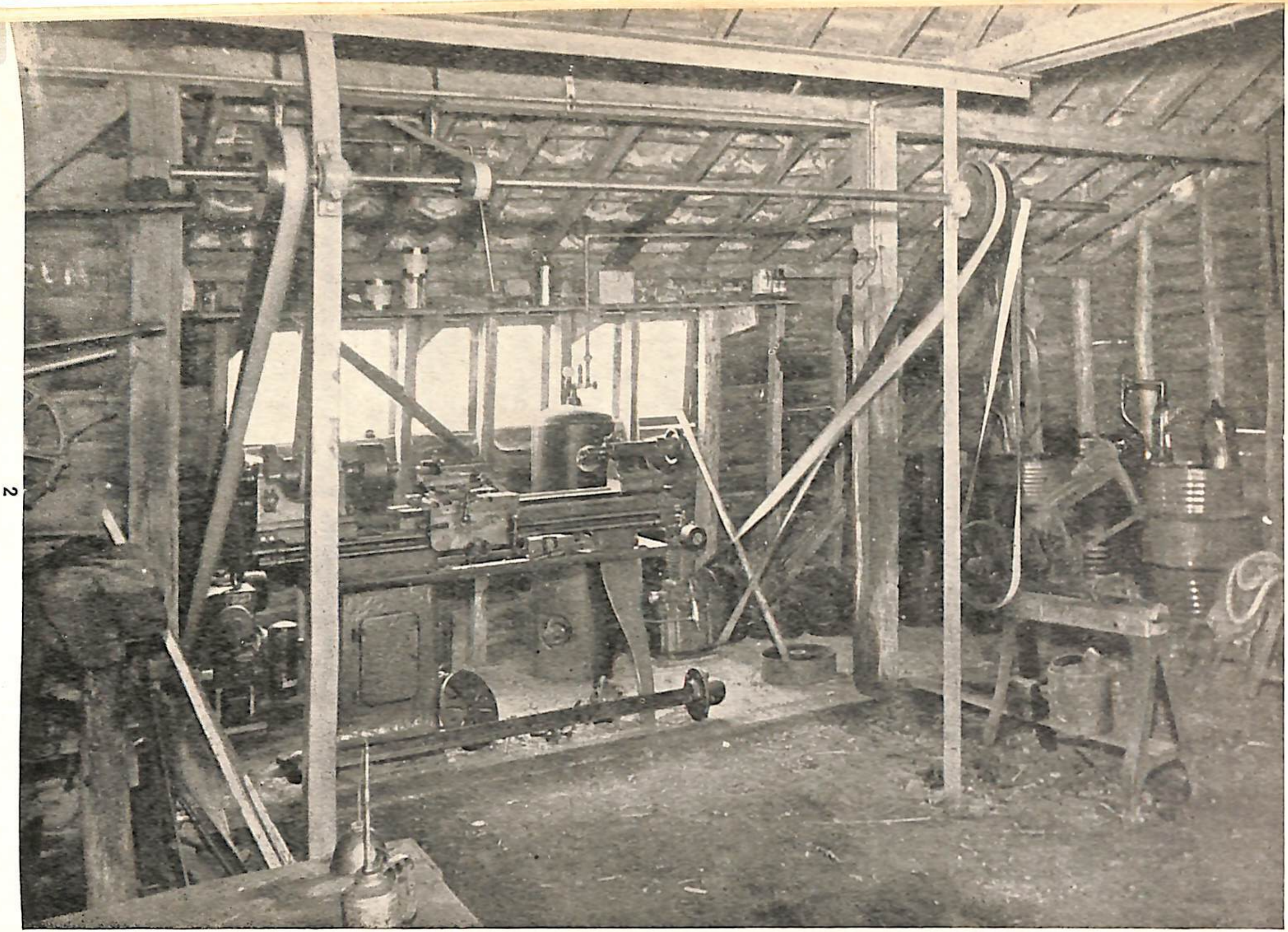


Fig. 2. Lathe, power hacksaw and compressor installed in existing building, with steel gantry to carry shafting.

Interior Fittings

Lighting is very important, and even though electricity may be installed, daylight is cheaper, so arrange for plenty of windows, especially over the benches. It may be pleasant to work by open doors when the weather is warm, but there should be no necessity for this in the winter. If mains electricity is available, install numerous points round the workshop so that not only can every corner be well illuminated, but lamps may be plugged in and taken to the machine under repair without having yards of cable lying about. A system of low-voltage lighting which is used extensively in garage workshops even though mains supplies are connected is given on page 4. Where individual machines, such as valve grinders and refacers, bench grinders, bench drills, and so on, are used endeavour to provide a light over each, for not all repair work can be done in daylight.

If the rafters are sufficiently strong, a runway for blocks and chains will save money on floor cranes, but when such an installation is contemplated, it is as well to get a good builder to test the beams and an engineer to erect the necessary steelwork, otherwise one may bring about the collapse of the whole roof.

Before undertaking any structural alterations it is wise to consider the nature of the work likely to be required. Tractor adjustments and general light maintenance work, including decarbonizing, do not need a great deal of equipment, as will be seen from the list on page 5. Much of the repair work necessary on implements, too, may be done with simple tools, but if a welding plant is to be installed, and it is intended to carry out the complete overhaul of machinery, then larger appliances are necessary and a bigger workshop wanted.

One must consider, too, the hundred and one maintenance iobs that are required on the average farm, for doubtless the farm mechanic will not limit his repair facilities to tractor engines. He will probably be called upon to service electrical apparatus, dairy machinery, implements, and possibly do a certain amount of woodwork as well, such as repairing trailers, gates, etc.

It is therefore clear that plenty of bench space must be provided. If possible, this should be so arranged that each branch of the work has its own bench and apparatus. For example, electrical work should not be done on a bench used for woodworking or for engine repairs, otherwise much time will be wasted in clearing away unwanted equipment and litter. It is wise, too, to have a separate bench for soldering, brazing and welding.

Benches should be soundly constructed and firmly fixed. Timber suitable for legs is not difficult for a farmer to obtain, but brick or angle iron should not be overlooked as possible alternatives. The top of a bench should be not less than 2 ins. thick, and the planks should be faced on the edge to permit close fitting. If at least one part can be protected with a metal sheet so much the better.

The average tractor is about 6 ft. 6 ins. wide and 10 ft. long, so, as a minimum of 3 ft. should be allowed *all round* for working, a floor space of at least 12 ft. by 16 ft. should be kept completely free for that purpose. But other machinery will almost certainly be awaiting attention, and where possible this should not be permitted to interfere with the movement of the mechanic or his equipment.

Workshop heating should not be overlooked, and the possibility of using waste oil as fuel for a stove or a boiler is worth considering.

A Useful Lighting System

Reference has been made to low-voltage lighting, and this can be obtained through the mains if a transformer is fitted, or it can be run from batteries of 6 or 12 volts. Bare copper wires are run in pairs about 6 ins. apart at a height of about 8 ft. from the floor, and poles bearing copper hooks are used to pick up the current and carry it to 6- or 12-volt lamps on leads. These small lamps give adequate illumination for close work, and they are much less liable to damage than are mains bulbs. The system is safe, adaptable and cheap. Fig. 3 shows the arrangement, and, of course, any number of lamps may be hung on to the wires. Lamps are switched off by unhooking the wooden pole and hanging it on one wire instead of two.

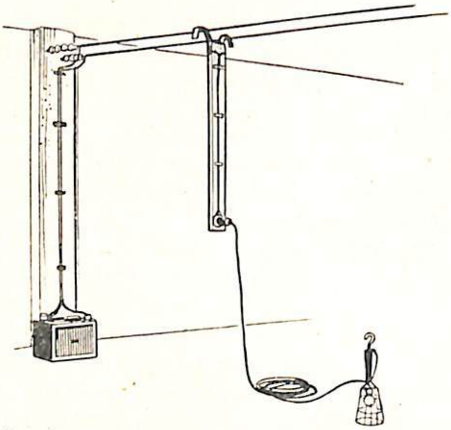


Fig. 3. A useful low voltage lighting system that can be installed where mains electricity is not available.

II

WORKSHOP EQUIPMENT

MAKESHIFT appliances are seldom economical of time, and the work done with them is often unreliable. It is surprising, however, how adaptable tools are in the hands of an ingenious mechanic, and an enormous variety of jobs can be undertaken so long as the basic tools are of good quality and well looked after.

The equipment need not be elaborate, but certain appliances are essential. Those listed below are sufficient for the maintenance, running repairs and seasonal light overhaul of the machinery on a medium-sized farm ; all of them are standard articles and can be bought at most ironmongers. The present cost of this set of tools is not much more than £50, and with care they will last for years. The only continuing expense would be for " consumable " articles, such as hacksaw blades and drills, and for replacing the few items that even the most careful workman may lose.

Heavy Equipment

Stove.
Bench—preferably of metal.
Carpenter's 7-in. vice for woodwork.
Engineer's 7-in. vice with renewable jaws.
4/5-ton jack.
1-ton pulley block and chains, mounted on 4-in. by 14-ft. sheer legs.

Hand Tools

Cold chisels—4 ins. by $\frac{3}{8}$ in., 6 ins. by $\frac{5}{8}$ in., 6 ins. by $\frac{7}{8}$ in.
6-in pin punch ; 4-in centre punch, 4 ins by 3/16 in. parallel punch.
2-lb. ball pane hammer.
Pin pane hammer.
2-lb. copper or rawhide hammer.
Adjustable hacksaw frame and blades (preferably 12 ins.).
Six bastard, second-cut and smooth files.
Engineer's 7-in. pliers.
$5\frac{1}{2}$-in. long-nosed pliers.
Three screwdrivers, 6 ins., 8 ins. and 10 ins.
Set of Whitworth open-ended spanners, $\frac{1}{8}$ in. to 1 in.
Set of American spanners, S.A.E. $\frac{1}{8}$ in. to $\frac{3}{4}$ in.
12-in. adjustable spanner.
24-in. Stilson.
Breast drill, $\frac{1}{8}$ in. to $\frac{1}{2}$ in. chuck.
Set of straight-shank twist drills, $\frac{1}{8}$ in. to $\frac{1}{2}$ in., rising by 64ths.
Grinding wheel, pedal-driven, with coarse and fine wheels.
Six carborundum sticks.
One pair tin snips, 8 ins. or 10 ins.
Soldering iron, $\frac{1}{2}$ lb. weight.

Blowlamp.
Oilcan.

Carpenter's Tools

Polished-head claw hammer.
28-in. rip saw.
16-in. tenon saw.
Six chisels, $\frac{1}{4}$ in. to $\frac{3}{4}$ in.
Oilstone.
7-in. wooden mallet.
Rachet-type brace.
Twist-bits, set $\frac{3}{8}$ in. to 1 in.
Pair 8-in. pincers.
Jack plane.
Spokeshave.

The above list may be considered the minimum, and it is more than likely that many of them, plus a few others, are already used. Any other appliance bought should be purchased for the time and labour it will save in the workshop, and this must always be the criterion.

Lifting Tackle

A considerable amount of repair work necessitates lifting and shifting, and one has the choice of jacks, cranes, blocks and chains, etc. A jack will not do the work of a crane, nor will a crane always replace a jack or a set of blocks and chains. Moreover, it is poor economy to make one tool do all the work of, say, lifting, for this is bound to hold up other jobs. In a busy workshop, for example, it may be necessary to have several jacks, a couple of floor cranes and possibly a block and tackle in addition. But when one is making a start it is best to proceed with caution and to select only that equipment which will be in constant use or which saves the most labour.

With regard to jacks, there are many types. There is the bottle jack, which is operated with a tommy-bar, and a similar tool which is hydraulic. The screw-type bottle jack has an extremely long life, and some are available which will lift up to 10 tons. On the other hand, they have only a short range of lift, so that although suitable for raising the axle of a car or a lorry they are not high enough to lift a tractor axle. It is true that blocks of wood can be used to raise the basic height, but that is bordering on the makeshift, and such methods are likely to prove dangerous.

The hydraulic jacks of the bottle type are a better investment in many ways, for they have a bigger range of lift. But their chief advantage lies in their easy and speedy operation, whilst the operator does not have to get so close to the job, and is consequently in a safer position. A further advantage is that this type of jack may be used as a press for forcing bearings in or out of their housing. The screw jack can, of course, be used as a press, but one has better control over the hydraulic type.

Then there is the jack which is lever operated, depressing the lever raising the jack crutch to the requisite height. These jacks have a ratchet mechanism so that the load may be lifted in stages thus making for easier working and more safety. The ratchet jack, however, has a fairly long operating handle, and it is often inconvenient, if not impossible, to work this in a crowded workshop. Hydraulic jacks overcome this disadvantage because for one thing they have a shorter lever, and because it is possible to raise the load even if the operating space is restricted to only an inch or two. The handle can then be removed.

Lowering the ratchet jack may prove dangerous if the load is a heavy one, unless the operator is in the right position to hold the lever securely. With the hydraulic jack it is merely necessary to turn a small wheel or move a trigger, when the crutch and its load will slowly sink. Movement may be arrested at any time, so that the load can be gently lowered to a definite position, such as when fitting together the two halves of a Fordson tractor. If an hydraulic jack is fitted with wheels, or placed on a strong-wheeled trolley, the whole may be run beneath the tractor (preferably on rails unless the floor is smooth) and the weight supported whilst the bolts are removed or replaced. Such a task would be much more difficult with a ratchet jack because invariably one finds that the correct position lies somewhere between two stops on the ratchet.

Hydraulic jacks—as well as the ratchet type—are available on low-wheeled trolleys that can not only be pushed easily under the vehicle or machine but can sometimes be used to move the load itself across the workshop floor. Both types of jack can be obtained either for low or for high work, the low model having a minimum height of about 7 ins. and a maximum of 15 ins., and the high-lift type ranging from 7 ins. to nearly 3 ft. The high-lift jacks should have wide-spread legs to give stability when under load, but it is not advisable to use these jacks as trolleys unless the shop floor is dead level and smooth.

It may pay to invest in a small crane, and these are generally mounted on steel wheels, so that once an engine or other component has been slung, the whole outfit may be pushed over to the bench or to the tractor. When moving the crane the load should be kept as low as possible should the crane tip over in striking an obstruction. It is also an advantage to fit a rigid bar between the load and the crane frame to prevent swinging.

Some floor cranes have screw-down bolts to ensure that the appliance does not move when an indirect lift has to be made. This is a feature worth having. All of the shop cranes of the type we are considering are manually operated, and can be obtained in various capacities, ranging from 15 cwt. to several tons.

A feature of some makes is that the jib is parallel with the floor, and it can be lowered to within half an inch of ground level. Provision is made for attaching a crutch pan instead of the hook, thus converting the crane into a useful high-lift jack. Cranes can, of course, be obtained with either fixed or movable jibs of the cantilever type, but the jackcrane is probably the most useful for the farm workshop.

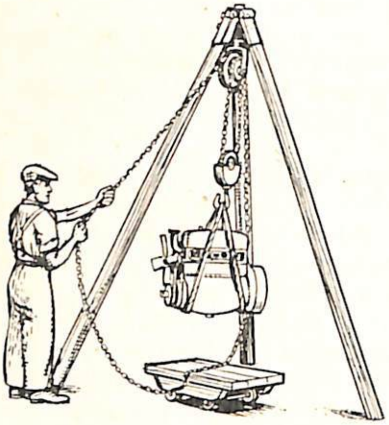


Fig. 4. A home-made hoist saves heavy lifting in the workshop.

For those who feel that a crane is an unjustifiable expense, and also where the workshop rafters are too weak to bear a heavy load, a Weston pulley and a wooden tripod will prove invaluable. The sheer legs should be of selected timber and as long as possible, for short legs mean more strain on the wood owing to the necessity for a wider spread. Wooden legs should not be less than 4 ins. thick. (See Fig. 4.)

Engine Handling Equipment

Engine stands are useful appliances in workshops which undertake the major type of repair. The stands consist of a rectangular frame of channel steel and are supported at each end on a trunnion. The legs of the stand are sometimes fitted with castor wheels. Engines may be clamped to the frame, which can be turned over so that the underside of the engine is readily accessible. Turning is usually through gearing, so that any tilt is obtainable, and the engine will remain firm in the set position. One make of stand—that of Messrs. Mann, Egerton Ltd., of Norwich—is also adjustable in width, for instead of a rectangular frame as a bed for the engine there are simply two side bars. This stand is therefore readily adaptable for several makes of tractor engine.

Axle stands are almost indispensable, for they can take the place of a jack, and so free it for use elsewhere. Most of the stands have three legs and are adjustable in height ; the usual range has about 10 ins. They are sold in pairs and made in three or four sizes, which provide for axles from 12 ins. up to 52 ins. from floor level.

No workshop is complete without a bench drill—operated by electricity, belt driven or hand operated.

Workshop Layout

The question of workshop layout is one which should be left to the mechanic, although he is advised to plan it carefully in order to avoid unnecessary carrying. The machine that is in for repair should not be far from the workbench or the tools needed for the job to be done. Where possible segregate the electrical workbench, for greater cleanliness is required here, and some of the tools and instruments are of a delicate nature.

Use plenty of shelves and make a supply of wooden or metal boxes for holding the dismantled parts of a machine. Smaller tins can be used for storing small stores parts.

Get into the habit of keeping both benches and floors clean, for this all helps to simplify work.

Tools for Engine Overhaul

So far reference has been made only to small tools and to the heavier items of workshop equipment, but if several tractors are used and the farm is highly mechanized the question of engine overhaul is worth considering. Such work may be divided into two classes ; first, the stripping down of both engine and transmission, and the fitting of replacement parts ; and, second, carrying out a complete overhaul, including re-metalling bearings, aligning bent connecting-rods, cylinder boring or lining, truing crankshafts and the general fitting and turning work such as is done by the agricultural machinery specialists. It is unlikely that these major repair jobs will be handled on the farm, but there are certainly possibilities in undertaking the services mentioned in the first class.

Even for these, however, some additional equipment is desirable. Electrically-operated valve refacers are probably the most important item ; and if electricity is not available, much of the work can be done with tools operated by compressed air. Failing this, a mechanic should not find it difficult to rig up an overhead shafting system and use a small petrol or oil engine to drive a bench grinder or (and this is of even more value) a flexible shaft grinder that will clear off carbon, reface valves, re-grind valve seats and do all the work of the more elaborate electrical outfits.

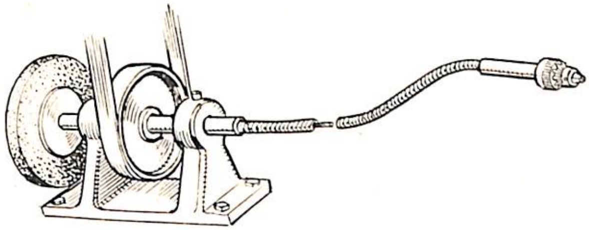


Fig. 5. A belt pulley mounted on a spindle can be used to operate a flexible drive to power hand tools.

Such a device as that shown in Fig. 5, for example, is simple to make and of enormous value. It comprises a belt pulley (driven from overhead shafting), and a spindle mounted in two bearings and carrying a grinding wheel on one end and a flexible drive and adjustable chuck on the other. The chuck can be used to hold drills, decarbonizing brushes of various shapes, a stiff wire brush for cleaning, a cloth mop for polishing, and many other similar tools. The whole apparatus should cost very little, and it will quickly repay the labour expended on its construction. Its value would be even greater if arrangements were made to provide for two or three different speeds—and many an old motor-cycle gearbox can be made to accomplish this.

Other equipment is described in those sections of the book which deal with specific jobs.

III

METALS

IT is not sufficiently realized how much a simple knowledge of metals helps the farm mechanic in his work. There are something like 50 different metals, although most of them are unlikely to be encountered on the farm, nevertheless they all have their individual characteristics and require different methods of treatment.

By far the most important metal is iron, for from it an enormous variety of steels is made. Were it not for iron we would have no electricity, for iron and steel are the only metals which can be magnetized.

Iron is produced from oxide of iron—commonly known as iron ore—and carbon in the form of coke or charcoal. When these two ingredients are mixed and subjected to the requisite heat, we get iron. There is no need to go into the processes by which iron and steel are made, for it is sufficient to know that there are three kinds of iron and a dozen or two steels.

Cast, or grey, iron is re-melted pig iron as it comes from the retorts, and it is used in considerable quantities to make cylinders for tractor engines. Cast iron contains a fairly large amount of carbon, so much, in fact, that it will blacken the fingers just as will a lead pencil. Cast iron has several characteristic properties ; it can be melted and poured into a sand mould ; it is brittle, and it is non-flexible. Thus it will not withstand shock, and should not on that account be hammered. It can be cut with a file and sawn, but it cannot be re-shaped unless first melted and poured into another mould. Normally cast iron is allowed to cool naturally, but if the outside of the mould is cooled quickly, the iron is known as chilled, and it has a much harder surface, due to the cooling action.

Another type of iron, known as *malleable iron*, meets the need for a material which has some of the properties of cast iron and some of mild steel, for it can resist shocks, which cast iron cannot. After pouring it into the mould, the metal is cooled very slowly, the period being from two to five days. This has the effect of toughening the casting, but not leaving it brittle. Malleable iron castings can be re-shaped when cold, but they cannot usually be welded, although brazing and soldering is possible.

An *annealed grey iron* is now being extensively used in the manufacture of farm machinery, and castings of this material will stand a good deal of bending. The metal has, in fact, many of the properties of a mild steel.

Steel is made from cast iron, but the quantity of carbon is reduced. A steel with a low carbon content may be forged, rolled or welded, and it is the material used in the building of bridges, etc. If more carbon is added, the steel takes on a new property, for it can be made very hard by heating it to a bright red and cooling it quickly. Such steel is used for making files, chisels and other cutting tools. The steel can also be tempered after hardening so that it possesses intermediate degrees of hardness. A hammer is usually made from carbon steel which is hardened at the face where it resists the impact of blows, but softer at the eye so that it will not split. A cold chisel, too, is hard at the cutting edge, and a little softer at the end, where the hammer strikes it. The lowering of the degree of hardness is called tempering, a process which is described elsewhere.

Tool steel, although exceedingly hard, may be tempered so that it can be cut and filed. Often the metal is first heated and then allowed to cool slowly, a process called annealing. After being shaped to the required size, it is again hardened, and then tempered to suit the work it has to do.

Steels are also combined with other metals, such as tungsten, nickel, chromium and so on, which makes the metal hard enough to be used for lathe tools, drills, reamers, etc.

A Guide to Identification of Metals

Not everyone can tell the difference between the various grades of iron and steel, and although the trained engineer can usually tell by " ringing " the metal on an anvil, and listening to the note given off, a simpler method is to touch them on a grinding wheel. Wrought iron, which contains little carbon, gives off long spear-shape sparks which are orange-yellow in colour. Mild steel gives orange-yellow spearheads, but, because of its carbon content, a few bright yellow stars. A medium steel gives very few spearheads, but many more stars, and a high carbon steel gives no spearheads at all, but all stars.

Non-ferrous Metals

Metals which contain no iron are known as non-ferrous, and they include copper, brass, zinc, tin, lead and aluminium. *Copper* is a particularly ductile metal, for it can be worked (i.e., shaped, cut, filed and so on) whether it is hot or cold. It is very easy to solder, but difficult to weld. It is also a good conductor of heat, and for that reason it is used for soldering irons. Copper that is hammered or rolled becomes quite hard, and to make work on it easier it is first heated and then plunged into cold water. This is sometimes necessary when fitting new copper piping to a tractor, for usually such pipes are sent out in the hard state, and bending is then much more difficult.

Brass is an alloy of copper and zinc, with usually a small quantity of lead added to make it machine easily. Like copper, brass is easy to solder, and, also like copper, it becomes hard when hammered or rolled. It is annealed or softened in the same way as copper.

Zinc is mostly encountered in sheet form, in which it is used for roofing or for lining tanks and shelves. It is used in the manufacture of brass, and is sometimes mixed with aluminium.

Tin is not often seen in its pure state, but it is used in the manufacture of solder and also to coat steel sheets. Tin cans are really made of tin-coated steel. The metal solders easily.

Lead is mostly used, so far as the farm mechanic is concerned, in the plates of batteries, and it is alloyed with tin to make solder.

As to *aluminium*, this is a metal which has come very much to the fore in recent years, for in addition to its use for crankcases and other castings for motor vehicles and tractors, it is made into sheets from which many articles are stamped. Aluminium cannot successfully be soldered or welded except by an experienced man with special equipment.

Alloys

An alloy is a mixture of metals or of metals and other substances. During the past few years considerable research has been made in this field, and some remarkable results obtained. One of the objects when making alloys is to obtain strength with lightness, and not only has this been successfully accomplished, but the resultant metal is able to resist rust and also corrosion to a remarkable degree. The actual number of alloys in use is enormous, and both tractor and implement manufacturers are continually trying out new alloys in an endeavour to overcome the inherent disadvantages of iron and steel.

It is perhaps with aluminium that the greatest progress has been made, and the alloy known as Duralumin possesses extraordinary tenacity and hardness, besides being ductile (i.e., workable). Duralumin is made from aluminium, copper, manganese and silicon. It can be rolled, forged, drawn and spun, and worked either hot or cold. Metals of this type may soon be used in the construction of many types of farm implements, and it is obvious that when that time comes the mechanic will need to know how to treat them.

IV

ELEMENTARY MECHANICS

HOWEVER simple or however complex a machine is, it utilizes one or more of the basic principles of mechanics. A plough, for example, is a development of the wedge principle, and so is the screw.

No work can be done, whether by man or machine without some corresponding expenditure of energy. A man uses a machine to save himself physical labour. He also uses his brain for the same purpose. Thus a knowledge of simple mechanics serves two very useful purposes—it enables one to keep machinery in good order and to cut out unnecessary manual work.

It does not necessarily mean that one must study a great deal in order to know something about mechanical principles, for although we may not realize it, most of us are already familiar with many of them. When we split wood, for instance, we utilize the principle of the wedge. When we cycle home at night we are using the principle of the lever. We use it, too, when we crank the tractor, or wind up the water from the well or turn on the water tap in the yard.

Probably we use the lever more than any other, for it has so many applications. But we do not always use it in its simplest form. For example, when we cycle we press on the pedals, and by means of leverage—in this case dependent upon the length of the crank—turn the chainwheel. The force exerted is used to revolve the sprocket on the rear wheel of the machine, and there is movement between the links of the chain. Unless oiled, the chain will become difficult to bend and straighten.

A machine is, therefore, an appliance which utilizes one or more principles of mechanics, but less effort is needed if friction is reduced, for friction is a force which opposes movement. A knowledge of mechanics, even if only the mechanics of friction reduction, helps us to work more easily.

As has been implied, a machine is a device for converting one form of energy into another, and the more economically this is done, the more efficient the machine.

Principles of the Lever and Wedge

The two chief mechanical principles used are the *lever* and the *wedge*, and each has a large number of variations. The lever is probably one of the earliest forms of mechanism discovered by man, and it consists essentially of a rigid bar which pivots round a point known as the *fulcrum*.

Three common applications of the lever are shown in Fig. 6. (a) Shows the weight to be lifted on the top of the lever, the fulcrum under it at a point close to the weight, and the force or effort applied in a downward direction. The closer the fulcrum to the weight the greater the leverage and the smaller the effort required to move the weight. When the weight and the fulcrum are near each other, the movement of the weight is small when compared with the movement of the other end of the lever.

The amount of work done is therefore in direct proportion to the distance through which the weight moves and the force needed to move it. Because of this, the unit of work is measured in terms of the foot and the pound, and is known as the *foot-pound*, or amount of movement and the amount of force.

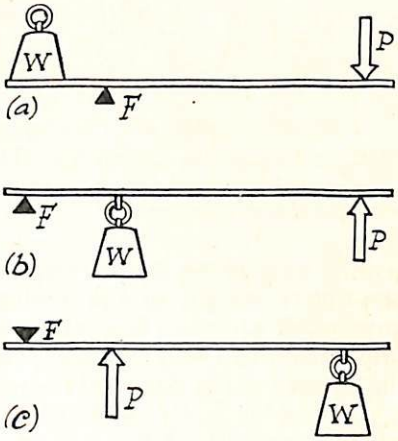


Fig. 6. Three common applications of the lever principle.

The power resulting from the application of a force is known as the rate, and the British engineer's unit of measurement of the rate is given in terms of "*horse-power.*" One horse-power represents the expenditure of 33,000 foot-pounds of energy in one minute. Lifting a weight of 33,000 lb. a distance of 1 ft. therefore requires—in theory, at any rate—exactly the same effort as moving a weight of 11,000 lb. a distance of 3 ft.

The second application of the lever is shown in (b), where the fulcrum is under the end of the bar, the weight to be lifted suspended from the bar, and the effort applied in an upward direction. Thus a man who lifts a cart axle by putting a lever on a box and lifting the other end of the bar is using this application of the lever.

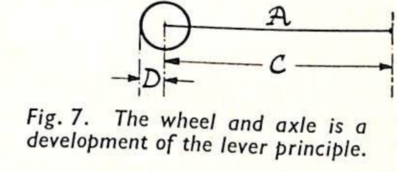


Fig. 7. The wheel and axle is a development of the lever principle.

In (c) the fulcrum is on top of the lever and the weight suspended from the other end. The force, therefore, has to be applied between these two points and in an upward direction. This application is seen in the crane in which the jib is anchored on the crane structure and the jib end raised and lowered at a point shown by the arrow in (c). Lift of the load is usually accomplished by separate means, although it need not be.

Another development of the lever is found in the wheel and axle, as the foregoing simple diagram (Fig. 7) shows. (A) Represents a single spoke of the wheel, and (B) the axle which revolves about its centre point or axis. The degree of leverage is represented by C (which is the spoke length plus half the axle diameter) and (D), which is the other half of the axle diameter.

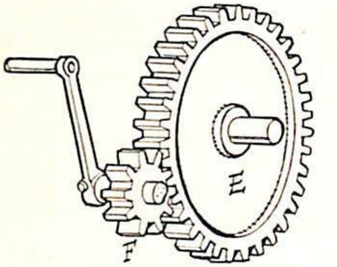


Fig. 8. A practical example of the lever principle as found in a hand winch.

When two wheels are in mesh so that the circumference of one engages with teeth on the axle of the other, turning the wheel marked F (see Fig. 8) exerts an enormous force on the circumference of the wheel (E), and this wheel would, of course, revolve slowly in comparison. A practical example of this principle is found in the tractor winch and in a gearbox.

The second simple mechanism is the *inclined plane or wedge* (see Fig. 9). This can be used so that a small force will raise a large weight vertically, by rolling or pushing it up a slope or inclined plane. Instead of lifting the entire weight of the object vertically, part of the weight is supported on the plane and part by the force. A more familiar application of the principle is found in the screw which is really an inclined plane wrapped round a cylinder.

The wedge is a modification of the inclined plane, and it will be apparent that when any form of wedge is used there must be *friction* between the two sliding surfaces. It is an important part of a mechanic's work to see that this friction is reduced to the minimum. Friction may be reduced either by interposing a lubricant between the rubbing surfaces or by altering the rubbing movement into one of rolling (as when using ball or roller bearings). This subject is dealt with in detail in chapter XII.

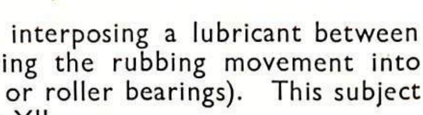


Fig. 9. Showing how a small force can raise a weight vertically by use of the inclined plane.

Energy

Whenever anything is moved there is a *resistance* to be overcome which necessitates the use of a *force*, or *energy*. This energy is not always obtained direct from the source of power, for there is an energy known as *potential*, and this depends upon the position of the body possessing it. In a pendulum clock, for example, weights are suspended on ropes or chains, and they possess potential energy in proportion to their height. As soon as a hammer is lifted, it possesses potential energy, and to this is added the muscular energy of the holder when he drives a nail. The greater the force behind the hammer the greater is its speed.

The energy possessed by a moving body is called *kinetic.* The flywheel of an engine possesses kinetic energy that is sufficient to compress the charge in the cylinder. If a small engine used for pumping water is not sufficiently powerful on a deep-bore hole, it is possible to increase its power by fitting a larger flywheel.

Energy is something that cannot be destroyed. It may not, of course, always do useful work, but it has to do something. A car that is travelling along a road possesses kinetic energy, and if the car runs into a solid wall, the stored-up energy is expended in smashing the car. But if the brakes are applied, the energy is transformed into heat by means of friction, and the heat is dissipated into the air through the brake drum and other parts.

Centrifugal force is a further example of the energy contained in a moving body. In this case, if a body moves in a curved path, an outward or centrifugal force acts on it and tends to make it travel in a straight line. It is thus that a car sways outwards when rounding a curve, and it is this principle which is utilized to govern the speed of a tractor engine or a gramophone turntable. Fig. 10 explains the application of centrifugal energy to a governor control; (B) is a shaft to which is fastened a disc (A). Attached to the edge of the disc are two thin flat springs (C) bearing lead weights (D). The lower ends of the springs are fastened to a plate (E). If the shaft is rotated rapidly, the whole unit revolves, but centrifugal force throws the weights outwards so that the springs become curved and the plate (E) is lifted. In a gramophone, the plate rises until it touches a brake, which, by causing resistance, slows down the speed of rotation. A drop in speed lowers the plate (E), so that the centrifugal force in the weights again takes effect and raises it once more. In this way the turntable is maintained at a constant speed. A similar arrangement is used to govern the throttle opening of a tractor engine, although in this case movement of the plate (E) would be transmitted by rods to the carburetter.

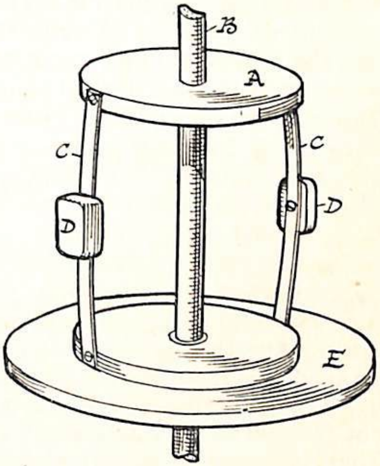


Fig. 10. The principle of using centrifugal force on a governor control.

Examples of the forces mentioned, also the two mechanical principles (wedge and lever) can be found by studying any machine, and it is an appreciation of these things which makes a mechanic's work so interesting.

V

PRINCIPLES OF FITTING

FITTING may be defined as making or repairing a metal article, and it is accomplished by using engineering skill and certain tools. The requisite skill in handling tools can come only by practice following upon sound instruction ; but, even so, the successful repairer understands the basic principles of machinery and thinks out in advance the best method of applying his knowledge to the job in hand. Bad work and tool breakages are practically always due to lack of care and to ignorance of the nature and capabilities of one's tools. This chapter therefore deals with a number of hand tools, and shows how they should be used.

Files

Files seldom get the attention they deserve, possibly because they are not properly understood. A file is a piece of hard steel having a large number of teeth which chip away fragments of the metal being filed. Not all files have the same size or number of teeth, for not all metals respond in the same way to a cutting tool of this nature.

The choice of a file for a given piece of work depends upon the amount of metal to be removed, the structure of the metal itself, and the degree of finish required. For instance, when it is necessary to remove a good deal of material, a rough file is generally used. This may have but 20 teeth to the inch. For smoother work a file with 50 or 60 teeth per inch is used, whilst for finishing off a job a " dead smooth " file having 100 teeth to the inch is needed. There are six grades of files, known by the following terms :—

Rough	20 teeth to the inch
Middle	25 teeth to the inch
Bastard	30 teeth to the inch
Second cut	40 teeth to the inch
Smooth	50–60 teeth to the inch
Dead smooth	100 teeth to the inch

An examination of a number of files shows that some have teeth cut in a series of single rows set at an angle of 60° across the file. These are known as " single-cut " files, and are used on very hard metals. The most generally used file has teeth cut in double rows, one crossing the other. It is known as a " double-cut." Some files are flat, with parallel sides ; some are tapered ; others square in section. There are also round, triangular and half-round files, each of which is better for certain work than any other. When buying files it should be remembered that the dimension for length refers to the blade only and does not include the tang.

Much of the skill of a mechanic lies in the way he uses his tools, and filing is one of the most important of the hand operations. It is not particularly easy to master, especially if one has never been shown the correct way and has got into the habit of see-sawing the file across the metal, using any file on any metal. It is best to use a new file on the softer metals first, and then as the keen edge gradually wears down to use it on other and harder metals.

Half the art of filing correctly lies in taking up a proper stance in front of the vice. With the left foot slightly forward under the bench, stand with the weight balanced fairly evenly on the two feet, but coming rather more on to the left as the file is pushed forward. The work should be set at elbow height, if possible. The handle of the file is grasped so that the end comes comfortably in the palm of the right hand, the left holding the extreme end in a manner which brings the top of the blade on the ball of the thumb where heavy cutting is required. (See Fig. 11.) For finer work the blade end can be grasped between the thumb and the side of the forefinger, which is curled round on the underside of the blade.

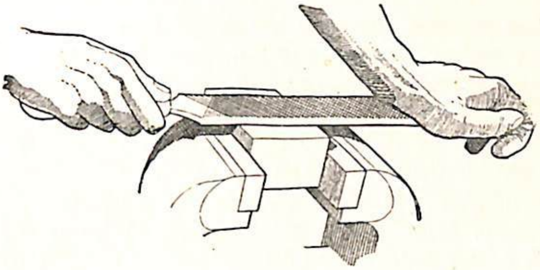


Fig. 11. Even pressure must be maintained on both ends of the file.

An even pressure on both ends of the file and a straight push on the forward stroke must be aimed at, but as a file does not cut on the return stroke, the pressure can be relieved and the file run back light. The blade should not, however, be lifted from the work, for drawing it back lightly helps to clear the teeth. If these instructions are followed carefully a really flat surface will result, and that is the sign of a good filer.

When filing circular stock to reduce its diameter, the file must, of course, be rocked so that it conforms to the diameter of the bar. The work can be held horizontally in the vice or it can be fixed vertically and the file worked round it. In this case, assuming that it is required to form a shoulder on a metal rod, a flat steel washer which just fits the rod should be slipped over so that it rests on the vice jaws, as in Fig. 12. The washer serves a dual purpose; it acts as a guide for the depth of the shoulder from the end of the rod, and it prevents the file from damaging the top of the vice. When using a flat file for this work, the safe edge—i.e., the edge without any teeth—would be in contact with the washer.

Round and half-round files are used in a similar manner to that just described, but they are given a slight curving motion in a clockwise direction on the forward stroke. This is not essential, but it results in a rather cleaner cut being made.

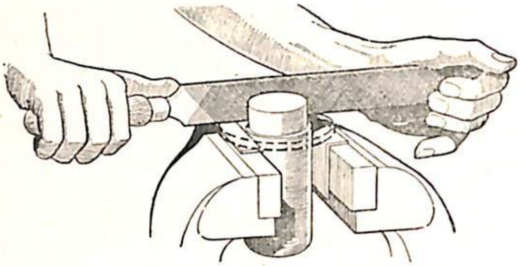


Fig. 12 A steel washer acts as a guide when filing circular stock and helps to form a true shoulder on the work.

It will be appreciated that, regardless of its shape, a large, rough-cut file is the best for heavy work, although a rough half-round file used with the flat side uppermost cuts better than a flat one, because the teeth clear themselves more easily.

Brass does not cut readily if a worn file is used, especially if it be of the rough-cut type, so it is advisable to keep some new files exclusively for the softer metals. The teeth of a file sometimes become clogged with filings, a condition known as "pinning." A file card, or wire brush, will remove the obstructions. Brush the file heavily in the direction of the slope of the teeth—i.e., *along* the teeth and not across them. When pieces of soft metal, such as solder, become embedded in the teeth it may be necessary to use the edge of a piece of tin to dig them out. Brushing the file over with paraffin or turpentine often prevents pinning.

Where a very fine finish is required on a piece of metal and a sufficiently smooth file is not available, it will be found very satisfactory to rub chalk into the teeth of an ordinary smooth file. This reduces the effective depth of the teeth, and therefore their cutting power. The chalk may subsequently be removed with a file card used as shown in Fig. 13.

There is no really practicable method of sharpening worn files, but it is sometimes helpful to immerse them for a few minutes in hydrochloric acid, afterwards washing them thoroughly in running water.

There are special files on the market to deal with aluminium alloys, as these materials are apt to clog the teeth of an ordinary file to a much greater extent than most other soft metals.

In view of the somewhat delicate nature of file teeth, these tools should never be thrown together in a drawer or left lying about on a bench, or they will quickly become damaged. Keep them in a rack at the back of the bench. A length of old leather strap makes a good file-holder, pockets being made by looping the strap before nailing it up.

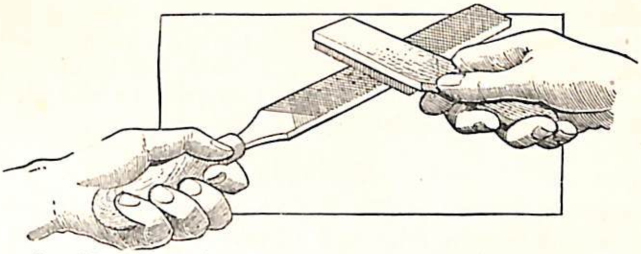


Fig. 13. Clogged teeth can be cleaned with a strip of file card tacked to a piece of wood.

The good mechanic always cleans a file before putting it away, and if the workshop is damp he will either dip the tool in oil or wrap it in an oily cloth.

Hacksaws

The tool used for sawing metals is the hacksaw. This consists of a steel frame (the adjustable frame is the best for general use), a handle, and a thin blade of properly tempered tool-steel. Blades are made in various lengths, and they are obtainable in different pitches (i.e., the number of teeth per inch). This is because some metals are cut best with a fine-toothed blade and others with a coarse. The blades are accordingly manufactured to meet these requirements, and are obtainable from 14 to 32 teeth per inch. For thin-walled tubing and for sheet metal less than 18 gauge, use a 32-toothed blade ; for copper and brass tubing, channel iron and sheet metal over 18 gauge use a 24-toothed blade ; and for aluminium, cast iron and most other solid stock use the 18-toothed blade. For general work a blade 12-in. long is favoured by most engineers.

To make a good job of sawing, make sure that the blade is taut in the frame and that the work is rigidly held in a vice. If the metal to be sawn is soft, use clamps of lead or wood to prevent the vice jaws from marking it. Start cuts by having the blade almost parallel to the surface, as this imposes less strain on the blade teeth, which should, of course, point away from the operator. Saw with a steady forward pressure and at a speed of about 50 strokes to the minute. Never increase this above 60. When starting the cut, use short strokes, lengthening them as the cut gets deeper, until the full length of the blade is in use. Another useful tip is to keep to the one sawing angle throughout, for changing it binds the blade and prevents its removal. The saw should be held at each end, and throughout the cut the blade should not be twisted or it will break. Do not bear hard on the blade during the cutting stroke, as should it snap there is a danger of cutting the hand. Always slow up on the last few strokes and raise the saw a little on the backward stroke to prevent the teeth from catching. Hold the blade so that the far end of the saw is slightly lower than the handle all the time and a see-saw motion avoided.

Chisels

Engineers' chisels are made of carbon tool steel, hardened and tempered at the cutting edge and a little softer where the hammer strikes. They have a large number of uses, including the cutting of grooves in bearings, cutting keyways in shafts and in wheel hubs and cutting metal sheets which are too thick for the shears or too awkwardly placed for sawing. Fig. 14 shows the most commonly used chisels.

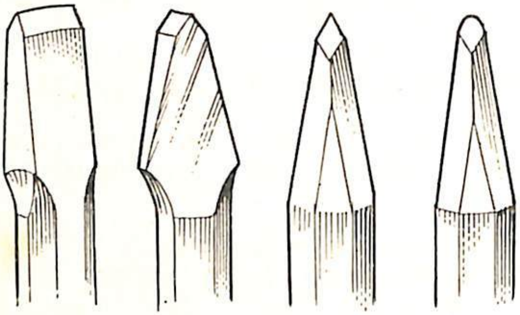


Fig. 14. Commonly used engineers' chisels.

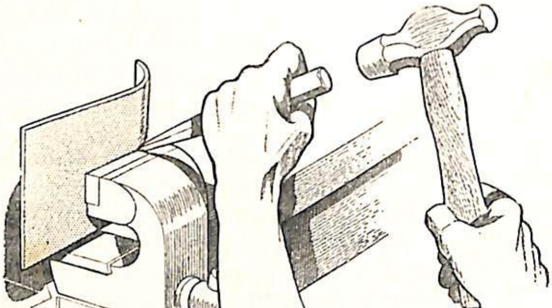


Fig. 15. The hammer and flat chisel used to shear sheet metal in the vice.

If the sheet is narrow it can sometimes be gripped in a vice so that the line to which it is to be cut runs as near to the jaws as possible as in Fig. 15. Place the chisel—in this case the flat chisel—against the work, and then tilt the blade slightly so that one corner is away from the work. In this manner the blade operates in much the same manner as a shear, and the work is more easily cut. Large sheets are best laid on a soft-iron block, and the cut started from the far end, working towards the operator. Here, too, the chisel should be tilted to obtain the shear action.

The flat chisel has, of course, many other uses besides cutting sheet metal, and it is extremely useful for cutting off rivet heads and nuts and bolts which have become rusted in. A round-nosed chisel is used for cutting oilways in bearings, and a cross-cut for keyways, with sometimes a diamond point for finishing them.

The best way to hold a chisel is to press it lightly against the base of the fingers with the second and third finger, leaving the first finger free. Don't look at the hammer nor at the chisel head, but at the work being cut.

After a time chisels become blunted, but may be resharpened by grinding. The angle for a flat chisel should be 60°, with the edge very slightly rounded, as shown in Fig. 16. Most engineers make up a template from a piece of mild steel, as this saves time in measuring the angle by other means.

When the cutting edge becomes too thick, as it will do after frequent grinding, the tool should be heated and drawn down to shape with a hammer and then retempered. Manufacturers have special gas or electric ovens for tempering, but for normal work the method described on page 149 is quite satisfactory.

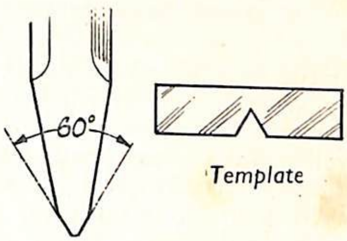


Fig. 16. A template saves time when sharpening chisels.

Drilling

Holes in metals may be made either by punching or drilling. Punching can be done only on sheet metal of thin gauge, so we will confine our remarks here to drilling. A drill is a precision tool made from carbon steel. It consists of a body which provides strength, flutes which guide the spirals of cut metal out of the hole, lands, and the cutting edge. These parts are illustrated in Fig. 17. The lands are narrow strips of metal which stand out from the flutes, and their purpose is to provide a clearance and also act as reamers to put the finishing touch to the hole. The flutes also ensure the correct cutting-angle, the normal degree of twist being 27½°.

As far as the mechanic is concerned, however, it is the cutting angle which is the most important, for upon it depends the sharpness of the drill. The standard cutting edge is 59°, although when drilling cast-iron or brass the best angle is from 45 to 50 degrees. It is therefore usual to keep a set of drills specially for these metals rather than to regrind them. When the metal to be drilled is very soft, the angle is made still greater, and for cutting thin brass sheet the drill is sometimes quite straight across, with an angle of 90°. These drills have a small projection or pipe in the centre to act as a guide.

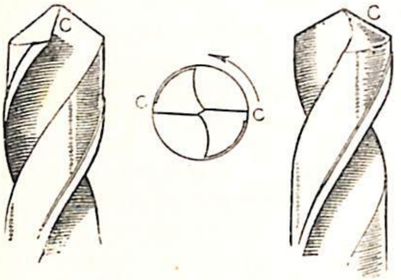


Fig. 17. The correct shape for the point of a twist drill. In each case 'c' denotes the cutting edges.

In addition to the cutting angle, it is necessary to have a clearance of 5° for the actual cutting edge. To obtain this requires a little practice, for sharpening a drill is not just a matter of rotating its end against a grinding wheel and getting the right cutting angle. By far the best method is to get a drill-grinding attachment for a grinding wheel, as this will save much time. A grinding attachment prevents the point of the drill being placed out of centre, as may well happen when ground by hand, and unless the actual point is midway, the drill will actually cut a larger hole than the diameter of the drill, and in this case, too, one edge will do all the work.

Where the metal being drilled demands a lubricant—and this is necessary if the drill squeaks—the following should be used :—

Metal	*Lubricant*
Aluminium	Paraffin.
Aluminium alloys	Paraffin and rape oil.
Brass and bronze	Paraffin.
Copper	Soapy water.
Cast iron	None needed.
Duralumin	Paraffin.
Monel metal	Lard oil 90%, turps 10%.
Mild steel	Soapy water.
Wrought iron	Soapy water.
Malleable iron	Soapy water.

Normally a lubricant is not required on brass.

Trouble is often experienced at the end of drilling a hole when the drill begins to break through the other side and lock with the frayed metal. As this may break the drill, ease the pressure. It sometimes helps if the drill is rotated in the reverse direction. Drilling machines are of many types, the hand, breast, bench and electric being the most common. The hand drill is suitable for light work only, the breast drill for slightly heavier work, and the bench drill for the largest drills. Electric drills will take anything up to $\frac{3}{4}$-in. so long as the motor is powerful enough.

Successful drilling depends as much upon correct marking out as it does upon the sharpness of the drill, and free use should be made of the centrepunch, which not only locates permanently the exact centre of the hole to be drilled, but it makes a slight depression to act as a guide for the drill point. If no punch mark is made, the drill will wander and make a hole anywhere but in the right place.

The usual procedure when marking out is to rub chalk over the area, and then to scribe two lines which intersect at the centre of the proposed hole. Place the centrepunch point exactly on the intersection and tap lightly with a hammer. Inspect to see if the point is correct. Should it be a little out, re-insert the punch but this time lean it to point in the direction of the correct location and tap again. When the right place has been found, put the punch vertical and strike a harder blow. If the incorrect punch mark is more than 1/16 in. out, ignore it and make another.

When more accurate drilling is required, scribe a circle the size of the finished hole, using the centrepunch mark as a centre. Then lightly punch four indentations around the circumference of the circle. These punch marks are known as " witness marks." Should the drill then run out of true, and this will happen unless it is held vertically, run a round-nosed chisel groove from the drill depression that is nearest the correct centre down to the centre, thus forming a fresh starting-point.

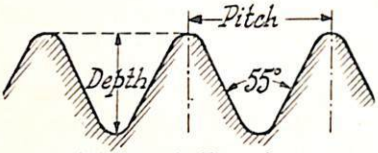
Select the correct size of drill, and make sure that it is sharp, then clamp the work securely in a vice or by means of clamps, etc., and insert the drill in the chuck. Push the drill shank right down to the bottom of the chuck or it may not be in proper alignment, and the drill may be broken. Once you have started drilling, do not try to alter the angle of operation. If a hand drill is used, turn the handle as rapidly as possible, and keep a steady pressure on the drill just sufficient to ensure a cut. Over-pressure will snap the drill if it is a small one.

When a hole has to be tapped, one is sometimes uncertain what size of drill to use, and it is recommended that a copy of " Tapping Drill Sizes " be purchased from the British Standards Institution, of 28, Victoria Street, London, S.W.1. The price, including postage, is 2s. Alternatively, a chart may sometimes be found in one of the engineering year books.

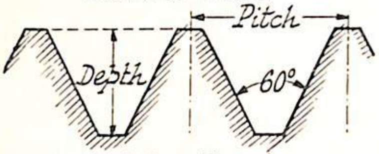
Thread Cutting

Cutting threads is a task which well repays care and understanding, for if a thread is properly cut, the nut will run along it smoothly and without slackness or binding. Screw threads vary in form a great deal, and this is because certain types are better for certain purposes than are others. In England, the Whitworth vee thread is one of the most commonly used in engineering work, but machinery from the United States mostly has the Sellers thread, so that it will be as well to understand the characteristics of each.

The Whitworth thread is seen at the top of Fig. 18. Note that there is an angle of 55° between the threads, and that both the point and the root are rounded. There is, too, a definite relationship between the depth of a thread and the pitch (the pitch being the distance between the two crests as shown in the illustration), and this depth is usually .64 of the pitch. The lower drawing shows the Sellers thread, and it will be noticed that the angle of inclination between the threads is 60° and that the crest and root are flat.



Whitworth Thread

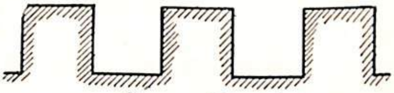


Sellers Thread

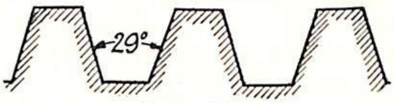
Fig. 18.

Another type of thread used a good deal is that known as the B.A. (British Association); the angle of this is 47½°, and the crest and root are more rounded than the Whitworth. You will also hear a good deal of a thread known as the B.S.F. (British Standard Fine). This is much finer than the Whitworth—which means that it has more threads for a given distance along the screw. This thread is used for screws and bolts which are subject to shock and vibration.

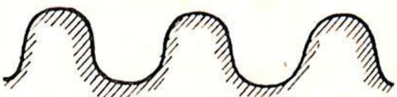
There are also other types of thread, see Fig. 19. The square thread, the knuckle thread, the Acme and the Buttress threads. The square thread is not quite so strong as the vee, but as the square has less friction to overcome it is used for transmitting motion, and is found on vices and on clamps, etc. The knuckle thread is on lathes, as also is the Acme, for the form of these permits the half-nuts to engage easily. In a lathe the cutting tool has to be fed along the job, and it is necessary that this movement can be started and stopped instantly. To accomplish this a long threaded bar is made to revolve in the front of the machine and a device consisting of a short tube threaded internally and split along its centre is made to clamp on to the revolving bar. To ensure speedy engagement, either of the two threads mentioned is used. The Buttress thread is usually found on woodworkers' vices, for in these appliances the thrust is mostly in one direction.



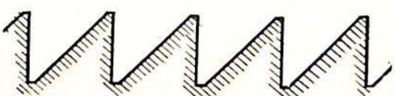
Square Thread



Acme Thread



Knuckle Thread



Buttress Thread

Fig. 19.

To cut a thread on a bolt or rod, a device known as a die is used. This is sometimes like a nut with clearance holes for the metal that is cut away. The die is made of cast steel and is hardened. Fig. 20 is of a stock and die, which is really a pair of dies (in this case a die comprises two halves of the " nut ") and a holder. The die cutters are held in the stock in vee guides, and there is a screw for pushing the two halves of the die closer together. The same stock can be used for several different sizes of die. The screw for tightening is drilled to take a tommy bar.

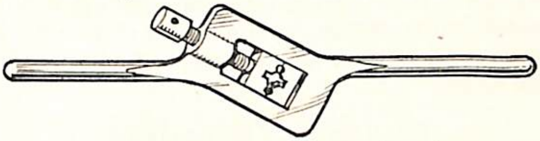


Fig. 20. Stock and dies used for thread cutting.

To use this type of die, the rod on which a thread has to be cut is slightly tapered with a file at the end, and then held securely in a vice. The dies are opened and the stock placed over the end of the rod, the screw is then turned and the dies closed until they just hold the stock in position. The stock is then turned (taking care to keep it level) and a shallow thread cut. Then the stock is turned in the reverse direction until it is once again at the top of the rod. The dies are then tightened up a little more and the process repeated.

When cutting threads on iron and steel be sure to use plenty of oil, otherwise friction of cutting will heat up the die and take the temper out of it. Carry on, tightening a little more each time until the thread has been cut to the correct depth. This is tested by using a nut which should run down smoothly but not loosely. Do not use dies on a rod which is too thick, as this always results in the thread being damaged, and sometimes completely stripped. If the rod is of smaller diameter and of soft metal, it might even break off. Use the dies carefully, therefore, keep the clearance holes free, and a perfect thread will result.

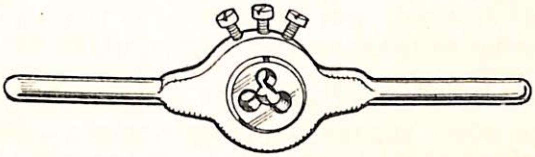


Fig. 21. One-piece die and stock.

Fig. 21 is of another type of stock and die. In this case the die is in one piece, but it has a cut to the centre which permits a slight opening and closing. The stock has three screws in it, the two outside ones being used to close the gap a little, so making the die smaller, and the centre screw serves both to hold the die in place and also to open it slightly. This die is used for smaller sizes, and when using it make sure that the flange on the stock lies above the die when cutting. Dies are chamfered on one side to give a lead-in, and often they are stamped with the words, " Start from this side." Obey this instruction as it will save trouble.

For still smaller sizes a device known as a die-plate is used. This may have up to a dozen different sizes of cutters, and it is a useful tool for small work, such as electrical equipment threads.

The die-nut is another useful tool. It is exactly like an ordinary nut except that it has clearance holes, and it is, of course, of cast steel and hardened. It is used chiefly for running down the threads of engine cylinder studs, for the ordinary stock cannot be used here. The die-nut is turned with a box or an ordinary spanner, and it is available in all sizes.

Internal Threading

Cutting internal threads is known as tapping, the tool being a fluted steel rod that is threaded like a bolt, with one end squared for use in a tap wrench. Taps are frequently sold in sets of three, one having a fair amount of taper, one with less (this is known as the second tap), and the third has no taper, and is called a bottoming, or plug, tap. This is used when cutting threads into blind holes, such as when fitting a stud. The first step is, of course, to drill a hole through or into the metal, and some care is needed to ensure that this is of the right size, for if it is too small the tap will jam and break, and if too large the thread cut will not be deep enough to ensure strength. The hole must, of course, be a little smaller than the diameter of the bolt to be screwed into it, and the right size for any screw may be found by consulting the tables printed in various engineers' year books.

To cut the thread, insert the taper tap in the hole and fit the tap wrench, and turn it gradually, keeping the tap vertical. Use great care when tapping, particularly with the smaller sizes of tap. Turn the tap a little at a time, for it must not be used as a drill, otherwise the chippings will not come out of the hole and the thread will be damaged. The best practice is to turn forward a quarter of a turn, then back a like amount. Use oil freely when tapping iron or steel, but on non-ferrous metals and most alloys it may be used dry.

Reamers

Reamers are useful appliances in any workshop, for, with their aid, holes may be enlarged, tapered, or all brought to exactly the same size. It should be made quite clear, however, that a reamer is not intended to take the place of a drill, but merely to true up or *slightly* enlarge holes. To force one end of a reamer into a hole and then press hard and turn it is to invite disaster, for the reamer is a somewhat brittle tool and one deserving care in use. To get accurate results—and this, after all, is the purpose of reaming—the tool should be allowed to scrape off only the last few thousandths of an inch of metal, and when one understands that a reamer is simply a scraper—or rather, a series of scrapers—set around a central rod, the folly of using it instead of a larger-sized drill will become apparent.

Reamers are made of cast steel, tempered and hardened, and the upper end is squared for use in a tap wrench. The tools are obtainable in several types, one having straight flutes, and another spiral flutes. Both may be parallel, or both slightly tapered. They may be obtained in a very wide range of sizes, ranging from those used by watch repairers up to those used in large engineering workshops, and of 2 in. or more in diameter. The general run is from $\frac{1}{8}$ in. to $1\frac{1}{2}$ ins., in steps of 1/64 in., and upwards in steps of 1/32 in. Reamers are also obtainable with Morse tapered shanks, so that they can be used in a drilling machine. There is one reamer which is both tapered and parallel, for the top half is parallel and the remainder tapered. Expanding reamers are used a great deal in the motor industry so as to save the expense of buying a large range of the fixed type. The tools are expanded by means of a wedge and screw, but such appliances should be used only by experienced men, as the cost is high and they are easily damaged.

Reamers with spiral flutes are generally used because they are slightly more accurate than the straight-fluted kind, which are inclined to " chatter " when in use. When reaming by hand, the tool should be turned slowly, but a little faster than the tap, and a steady pressure applied as the tool is turned at a uniform speed. A few drops of thin oil should be used as a lubricant.

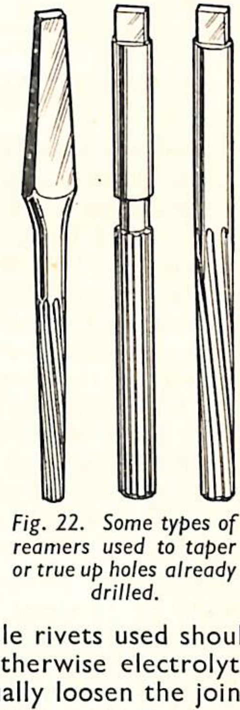


Fig. 22. Some types of reamers used to taper or true up holes already drilled.

Riveting

Riveting is a useful means of forming a semi-permanent joint between sheets of metal, but unless it is done properly it will actually weaken the metals. Before describing the various ways of riveting, it will be necessary to say something about the rivets themselves, for there are several kinds, each of which has been designed for a special purpose.

Fig. 23 shows some common types. As a rule rivets used should be of the same metal as that to be joined, otherwise electrolytic action is likely to be set up, which will eventually loosen the joint. Rivets are made from mild steel, wrought iron, copper, brass, aluminium, etc., and for tinplate work they are of tinned iron.

Countersunk-headed rivets are used on thickish materials when it is desirable that the finished join shall be free of projections : they are widely used for toolmaking, but are not often used on the farm except in the construction of some ploughs. Snap-head rivets are used more than any other type, particularly in the construction and repair of agricultural machinery, for they are enormously strong. There is another rivet often used for engineering work, and this is the "pan head." This has a round, flat-topped head, which tapers slightly from the shoulder where it joins the stem. Flat-headed rivets are usually made in the softer metals, such as copper, brass, and so on, and are chiefly used for light work, such as small tank construction.

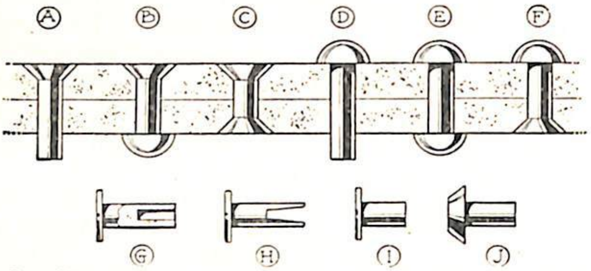
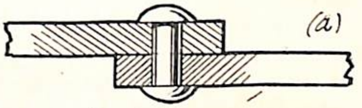


Fig. 23. A—Countersunk rivet, closed with snap head at B, or with countersunk head at C. The snap head rivet D similarly closed at E and F respectively. G—Hollow rivet. H—Bifurcated. I—Tinmans. J—Pan head.

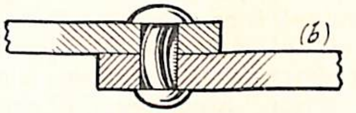
It is very important that when joining metal plates together, such as when making a simple lap joint, as shown in Fig. 24a, not only must the rivets be of the correct length but the holes drilled in the sheets must be of exactly the right size. The object when riveting is to fill the holes completely and not to have a bent rivet, such as that in Fig. 24b. Then, again, it is necessary that the rivets used are not too thin in comparison with the thickness of the plates. If, for example, the plates are half an inch thick (each), then the diameter of the rivet should be not less than three quarters of an inch, for should the join have to bear a stretching strain, the edges of the holes would tend to act as cutters, and will shear a rivet in two if it is too small in diameter.

Having selected the right type and diameter of rivet, the next thing is to get one of the right length. This should be such that, when the end is burred over, a strong head results. Roughly speaking, the amount to project through the hole in the plates should be $1\frac{1}{4}$ times the diameter of the rivet. If more than this is allowed the rivet will bend over instead of forming a well-shaped head, and if less is allowed the head will be so small that the joint will come apart when under strain.

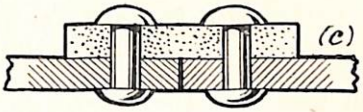
When drilling holes in plates, drill both plates together if this is possible, so as to ensure correct register, but if this cannot be done, make sure that the holes are as accurately positioned as possible. After drilling, clean away the burr formed by the drill. When a rivet is inserted in the hole, place the head on a firm surface and pean or clinch it over with a ball-ended hammer, taking care that the two plates are held tightly together in the process. Soft rivets are usually peaned over with the aid of a special tool, which is like an ordinary punch, except that the face has a shallow depression which fits over the end of the rivet. A very neat job results from the correct use of this tool.



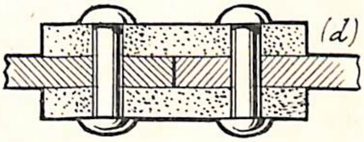
Single lap joint



Rivet too small



Single butt joint



Double strap cover joint

Fig. 24.

As will be seen from Fig. 24a, a single lap joint is made by laying one piece of metal on top of the other, but other methods, such as the single butt joint or a double strap-cover joint are often desirable. These joints are illustrated in Figs. 24c and 24d.

Rivets should be placed not more and not less than two rivet diameters from the edge, and not less than four diameters apart. Thus, suppose you are using $\frac{1}{4}$-in. rivets, the centre of the hole should be $\frac{1}{2}$ in. from the edge of the metal, and the holes 1 in. apart.

Clinching a rivet requires a certain amount of practice to accomplish properly, for upon it depends not only the strength of the joint but the appearance of the finished job. Start by placing the job, rivet head down, on a firm base, such as an anvil or a heavy vice, and then strike the rivet squarely with the flat of a hammer. This will spread the rivet slightly over the edge of the hole. Then use the ball end of the hammer and strike all round the edge, working round and round to form a shapely head. Do not direct the hammer blows vertically downwards, but direct them toward the centre. It is a matter of practice to get a good head with a minimum of blows, for too much hammering will harden the rivet and will, if carried to excess, tighten the plates so much as to buckle them. All the same, see that each rivet is firm.

Copper rivets are often used for joining leather straps, but in this case put a copper washer over the rivet before clinching. The hole in the washer should be only slightly larger than the rivet. A flat-headed hammer is the best tool for this work.

Soldering

Soldering is a method of joining separate pieces of metal using heat and an alloy called "solder." Solder is a mixture of tin and lead and has a comparatively low melting-point, although the proportions of tin and lead have the effect of raising or lowering that point. There are actually several kinds of solder—a plumber's solder, which has a lower melting-point than lead, because it is used to join lead pipes ; and tinman's solder, which is used for joining most other metals.

The most commonly used solder contains about half lead and half tin, and its melting-point is approximately 415° F. Being made of two soft metals, it obviously cannot make a very strong joint, and it should consequently never be used if breakage would result in injury of someone. There is another solder, called "hard solder," and this is composed of silver, copper, zinc, etc., and it has a melting-point of from 1,600° F. to just over 1,800° F. The use of this material is described later in this chapter. A third solder, usually called "spelter," is composed of copper and zinc and some other metals, and it is used for brazing, a subject that is also dealt with later in this chapter.

Soldering is by no means a difficult operation, but unless certain rules are followed, the results will be poor. The first essential is that the surfaces to be soldered must be clean and quite free from all forms of dirt, corrosion, grease, oil and tarnish. There are various methods of cleaning metals that are to be soldered, for scraping, filing, buffing with emery cloth or with sandpaper are all commonly used. The main thing is to see that the whole of the surface to be soldered is clean, particularly corners and cracks.

Although the surfaces may be cleaned properly, the metal has to be heated to enable the solder to flow properly, and heating has the effect of tarnishing the surface and preventing the proper adhesion of the solder. To overcome this the surface must be protected from exposure to air, and this is done by using a substance called "flux."

Fluxes

All fluxes have the same effect as regards the exclusion of air, but some of them not only remove the oxide tarnish, but also eat away the metal to be soldered. Zinc chloride, which is made by adding some small pieces of zinc to hydrochloric acid is one such corrosive flux, and for this reason it should never be used in the soldering of electric wires, because the flux will continue its action and eventually eat its way right through the wire. Borax is another corrosive flux, but this is used in hard soldering, as we shall see later.

As to the non-corrosive fluxes, rosin is the most common, and it can either be purchased in lump form and crushed to a powder before use, or it may be purchased as a proprietory article mixed with a wax or tallow. There has recently come on to the market a rosin-cored solder which is extremely handy and very efficient. Not all hollow-wire solders are non-corrosive, however, for some are made with an acid core.

The Soldering Iron

The third essential to good soldering is some means of applying heat to the prepared surfaces and to melt the solder itself. This is usually done by a soldering iron, which consists of a piece of copper bar, an iron rod riveted to the copper, and a wooden handle. Copper is used for the tip, or " bit," of the soldering iron because it conducts and gives off heat readily.

Heating of the iron may be from a blowlamp, gas-ring, etc., or it may be through an internal electric element. If no soldering iron is available but a soldering job has to be done, one may use a steel or a brass rod, although this will require more frequent heating. It should be " tinned " in the same way as a copper " bit."

Tinning

Tinning is the process of coating the working point of the copper bit with solder, as the bit naturally is liable to tarnish when heated, and a well-tinned iron readily transfers its heat to the objects to be soldered as well as assisting the melted solder to flow more easily. To tin an iron, heat it until rainbow-like colours appear on the copper head. This means that the iron is a little above the melting temperature of solder. Next remove the tarnish by rubbing the part to be tinned in flux and solder. It is useful to have a block of wood containing a small depression, and to apply flux and solder, rubbing the iron in this until the end is coated all round. It is, of course, not necessary to tin the whole of the copper, but only that part which will be used for coming in contact with the metal to be soldered. An iron will not need tinning every time it is used, and as a rule it is necessary only to heat it and dip the point into flux.

When the iron is tinned, heat it again until solder will readily melt when touched on it, and apply the iron to the surfaces to be soldered. These should, of course, have been given a coating of flux unless a cored solder is used. Rub the iron over the surfaces until a thin film of solder covers them. Remember that the metal is heated by coming in contact with the hot iron, so do not use only the point of the iron, but see that a flat part makes contact. Apply solder to the iron as it is moved over the metals to be joined, and see that the solder flows freely all the time. If it does not, then the iron is too cold. Do not apply a lot of solder, for a thin coat is actually much stronger.

Should it be necessary to solder a long joint—such as when attaching the bottom of a large can—place a drop of solder at intervals along the seam just to hold the two pieces of metal in position, then run along the seam as directed above. If the surfaces to be soldered are wide, tin each surface and then hold them in close contact either by placing a weight on them or by using some form of clamp, and then put the soldering iron on the metal so that the heat melts the tinning and the two surfaces fuse together. This is called " sweating." Finally, do not disturb a soldered joint until it has set and is comparatively cool. If a soldered joint is watched throughout the process one will see the surface of the solder cloud over soon after the iron has been removed. It will be hard enough to remove pressure a few seconds later.

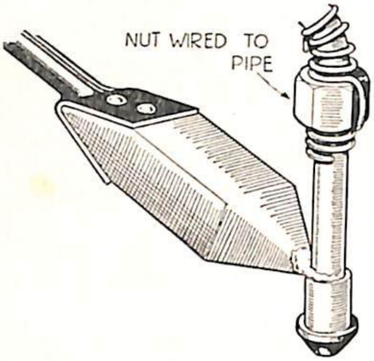


Fig. 25. Soldering on a fuel-pipe union. The nut is first threaded over the pipe and wired in position as shown.

Silver Soldering

It sometimes happens that an ordinary soldered joint would not be strong enough to withstand vibration and if trouble has been experienced and petrol pipe unions constantly break away, silver soldering should be resorted to. This is really a form of brazing, but it requires less heat, and is particularly well adapted for small jobs. The flux used is usually borax, but boric acid, or even a combination of the two, will do equally well.

The spelter—or brazing material—may be obtained either in wire form, or it may be obtained from an optician, in which case it is normally in small sheets. To silver-solder a petrol pipe union, first clean both the pipe and the union thoroughly and see that they fit closely together, for unlike solder, the spelter is expensive.

Cut a narrow strip of the spelter and bend it so that it will fit fairly loosely round the pipe, then pull it well back up the pipe. Now heat both pipe end and the union, and apply a little borax (mixed with water), using a small brush. Push the union on to the pipe and apply a little more of the flux, and then slide the spelter ring down until it rests on the nipple. Keep in the flame until the spelter melts, and then remove it, and the job is done. When it is necessary to silver-solder two parts which cannot be fitted together as the pipe and union, set one part firmly on a base and clamp the other in such a manner that it will lightly press on to it in the right position for brazing. Apply flux and heat, then place a small piece of spelter between the two surfaces to be joined, taking care not to upset the light contact, and then heat until the spelter flows.

Brazing

Where specially strong joints are required, a solder repair is insufficient, and recourse must be made to brazing. For this operation a fairly powerful blowlamp, or a gas blow-pipe, is required, together with a supply of brazing wire, or spelter, and flux. The work is carried out at a bright-red heat, so that if the parts to be brazed are large, a lamp with a capacity of half a gallon or more is needed, and a small brazing hearth will help to conserve the heat. Fig. 26 shows two brazing hearths, one for gas and the other for blowlamp use. This latter one can be made out of an old 5-gallon oil drum cut to the shape shown. Charcoal, used coke, asbestos, or broken firebrick should be placed in the hearth to ensure the even distribution of the heat.

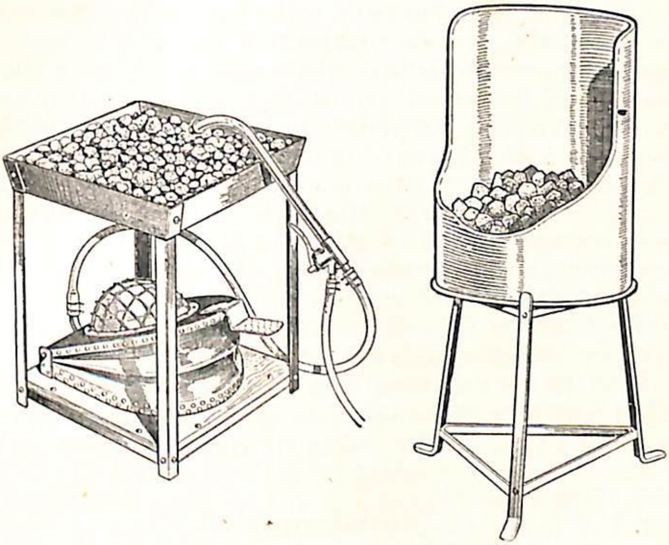


Fig. 26. Brazing hearths: on the left for gas, on the right for blowlamp use. The latter can be constructed from an old 5-gallon oil drum.

By way of illustrating the process, imagine that the yoke on the end of a brake rod needs reconditioning through wear. Assuming that the holes in the yoke have worn oval, they may be opened out with a drill or a reamer to take the next available standard size in commercial steel rod. A piece of rod, which should be a good fit in the enlarged holes, is then driven through the yoke. The rod is cut off so that the ends are just " proud " of the yoke faces on both sides. Although not necessary in this case, there are many brazing jobs in which it is necessary to pin the two parts firmly together.

Before the yoke and rod are assembled preparatory to brazing, make up a stiff paste of borax and water and paint it on the rod.

Then stand the assembly in the brazing hearth and surround the joint with the coke or whatever material is used, leaving an opening in the front to allow the blowlamp flame to play on the joint and to provide room for manipulating the brazing wire.

The joint must be heated to a distinctly bright red, when the end of the brazing wire can be held in the lamp flame for a few seconds to warm it before dipping it into the flux. A small quantity of this flux will adhere to the end of the wire. Touch the wire on to the joint, and the flux will at once flow readily into the joint and over the general surface, and if the heat is sufficient, the wire will melt and run into and around the joint. Apply more flux and a little more brass until enough has been melted to ensure that the whole inner surface of the joint is covered.

The lamp flame can now be withdrawn and the joint allowed to cool down slightly—just enough, in fact, to ensure that the brass has solidified. The job is then lifted out of the hearth and brushed vigorously with a wire brush to remove the semi-molten flux which will be adhering to it. This is done to reduce, as far as possible, the labour of cleaning-up the joint when cold, as the flux takes on the appearance and hardness of glass, and is, therefore, more difficult to remove with a file. After brazing, the projecting ends of the rod are filed flush with the yoke faces, and the new holes carefully drilled. To complete the job, the part of the rod between the yoke jaws is cut away with a hacksaw and the inner faces trued up with a file. When all surplus metal has been removed, the joint may be polished with emery cloth. One of the secrets of brazing is in doing the job quickly and avoiding heating the metal more than necessary.

Blowlamps

The blowlamp is an extremely useful piece of equipment to have on the farm, for not only can it be used for heating soldering irons, but it will be handy for heating nuts which are stuck on a bolt, warming a tractor intake manifold on a cold morning or thawing a frozen pump or water pipe. Most blowlamps use paraffin as their fuel, although there are many that will take petrol as well, and some which require petrol only. If petrol is used, do not use a leaded fuel, as the fumes of combustion are poisonous.

Most blowlamp troubles are caused through improper treatment or through neglect. Pump leathers sometimes dry out, and if the lamp has not been used for a long time, it will save bother if the leather is oiled before the lamp is put into service. Another common trouble is failure of the check valve at the bottom of the pump. In some makes this valve is made of cork, and is held on its seating by a spring. Whatever the type of valve, both the ball and the seating should be quite clean, and in case of trouble dismantle the pump and wash all the parts in paraffin before re-assembling them.

Leaky joints may be stopped by unscrewing them and applying a little hard soap. If the gland leaks, close the valve tightly and then tighten up the stuffing box slightly. Never overdo this tightening of a gland, or the valve will be too stiff to function properly.

When you have finished using a blowlamp, shut off the control valve, and, when the flame has gone out, slightly open the valve again. This will assist in keeping the jet clean and wash away any carbon that has formed. It is useful to remember that if a valve is shut tightly and left in that state, the metal parts contract as they cool, so that the valve may be jammed when next the lamp is needed. If a lamp is to be put away for a longish period, it is advisable to empty the fuel and to leave the jet valve slightly open.

When heating a soldering iron in a blowlamp, do not let the flame play directly on to the tinned end of the iron, as re-tinning will be necessary. Copper is an excellent conductor of heat (that is why it is used in soldering irons), so it is sufficient to play the flame upon the body of the iron.

Abrasives

When used intelligently, abrasives perform a most useful purpose in a workshop. Abrasives, as distinct from grinding wheels, which are dealt with elsewhere, are of several kinds. There is emery paper and emery cloth, crocus cloth and crocus powder, carborundum powder and paste, and various abrasive stones which are generally used for putting the final cutting edge on certain tools.

Emery cloth is used for hard metals, such as iron and steel. It consists of powdered emery glued to cloth in much the same way as sand is glued to paper for woodwork. Emery cloth is obtainable in various degrees of fineness, ranging from 000 (the finest), 00 and 0. Then in the medium range there are Nos. ½, 1, 1½ and 2; while very coarse is No. 2½ or No. 3, although the latter is seldom used. The mechanic will probably find Nos. *0, 1, 1½ and 2* sufficient for all general purposes, although a few sheets of 000 are useful for the finest work. It is usually better to back up emery cloth with a strip or block of wood, particularly if a flat surface is required.

Crocus cloth is iron oxide (rust) glued to cloth, and it is an extremely fine abrasive which produces a high polish on soft metals such as brass, copper and aluminium. Coarse abrasives scratch these metals too deeply.

Wire brushes and steel wool are other abrasives, and are used mainly for cleaning off rust scales and so on. Steel wool can be used effectively for polishing metal or for general cleaning. Several grades are available, but use the fine on soft metals.

It is dangerous to use emery cloth on soft metals, because particles of the abrasive become embedded and are difficult to remove. Emery should not be used on any electrical machinery (neither should steel wool or carborundum), as most abrasives are conductors and may cause a short-circuit. Commutators of motors and dynamos should be cleaned with fine glasspaper, and then thoroughly cleaned out with an air blast.

A little thin oil applied to emery cloth makes it finer, and is often used in the final polish.

Grinding Wheels

An indispensable appliance in any engineering workshop is a bench grinder. It may be hand operated, driven by electricity, or run from overhead shafting, but whatever means of rotation is used, it is the grinding wheel itself which is the most important as far as the mechanic is concerned.

The two essential parts of all grinding wheels are the abrasive, which does the actual work of cutting or grinding, and the bond which holds the abrasive particles together. Abrasives are selected according to the work they have to do, and both their degree of hardness and their size vary a great deal. Silicon carbide is the most commonly used abrasive, particularly for the low-tensile-strength materials such as cast iron, brass, bronze, aluminium, and so on. This material is very hard, but somewhat brittle, and for high-tensile grinding an aluminium oxide is recommended, as it is less liable to fracture.

When a grinding wheel is in operation, the sharp abrasive teeth cut small chips from the metal, but in doing so they sooner or later become blunted. When this happens there is a great strain upon their anchorage and they are torn away, leaving new teeth or crystals to carry on the work. Thus a grinding wheel is always sharp, right to the end of its life.

Although the two most commonly used abrasives are silicon carbide and aluminium oxide, they are not always known by those names, for each manufacturer has his own trade name. Thus it will be found that silicon carbide is known as Carborundum, Unirundum, Crystolon, etc., and aluminium oxide as Bauxilite, Aloxite, Alundum, and so on.

The bond is generally clay and fusible materials, and, after being thoroughly mixed with the abrasive, it is put into moulds and pressed hydraulically. Then after it has been dried it is put into a kiln, from which it emerges as the finished wheel. It is during the mixing of the bond and the abrasive that the " structure" of the wheel is determined, this being the proportion of bond to abrasive, giving the size of the air space between the grains and the bond posts.

There are three terms used in grinding-wheel manufacture which the mechanic should know, and these are the " grade," " grit " and " structure." The grade indicates the relative strength, or holding power, of the bond, for when this is increased in quantity, the wheel is hard. The grit refers to the size of the crystals of abrasive, and these range from the very coarse to the very fine, and are usually stated in numbers which represent the screen through which they pass. Thus a No. 10 grit means that the grains will pass through a screen having 10 lines per linear inch, and a 400 grit means that a screen having 400 lines per linear inch has been used. The structure has already been explained.

Manufacturers all have their own system of marking their wheels. For example, Norton Abrasives may mark a wheel " 3846-K5BE." The first two figures represent the kind of abrasive used, in this case it is a brand of Alundum. The next pair of figures (46) refers to the size of the grain, and the 46 is a medium grain. K means the grade, and this manufacturer has five groups : Very soft, E, F, G. ; soft, H, I, J, K ; medium, L, M, N, O ; hard, P, Q, R, S ; and very hard, T, U, W, Z. Thus the wheel we are discussing is of a soft grade. The next (single) figure (5) refers to the structure, and in this case it is of medium spacing. The last two letters (BE) designate the type of bond that is used, the vitrified (i.e., clay and fusible materials) being given these two letters. Thus our wheel 3846–K5BE is a silicon carbide wheel with a medium grain size, is soft and with a vitrified bond.

Successful grinding does not only consist of having the right type of wheel, for although the silicon carbide wheels should be used on low-tensile materials, one should obtain a coarse grain for the soft materials and a fine grain for hard, brittle materials. Then, too, a hard wheel should be used for soft metals, and a soft wheel for hard ones. Use wide grain spacing for rapid removal of material.

The area of contact must also be considered, for the smaller this is the finer should be the grain of the wheel. Lastly, one has to consider the wheel speed, for the higher this is the softer should be the wheel. For most purposes likely to be encountered in the farm workshop, a surface speed of 5,000 f.p.m. is best, and it should be borne in mind that a larger wheel has a greater surface speed than a small-diameter wheel when the spindle speed is the same. One may gather from this that as a fast wheel cuts better, and is harder, slowing down the surface speed makes the wheel operate as a soft one. This is useful on occasions when a softer wheel is not available.

Do not expect, however, that a single wheel will do every job equally well. If the surface glazes, then the wheel is too hard for the job, and although this can, as explained, be counteracted a little by reducing its speed, it is better to fit a softer wheel if possible. A wheel which wears rapidly is too soft.

With regard to grinding in general, always fit a work-rest, and see that it is close to the wheel face, otherwise the work may catch between the wheel and the rest. Do not force work hard against a cold wheel, as the sudden heating may break the wheel.

Finally, see that the grinder is fixed firmly and that it does not vibrate, and that the bearings are well oiled.

Welding

Welding is the joining of metals by means of heat, and the elemental principle of the process is seen in the blacksmith's shop, in which two pieces of metal are heated to a bright red and then hammered together until they become almost as one. In a good weld by this means, the join is approximately 75 per cent. as strong as the metal itself. This type of welding is now practically confined to the blacksmith's shop, and used extensively in the repair of farm machinery. Many smiths, however, now undertake oxy-acetylene welding, not only because it is quicker, but it is stronger. It is possible, too, to weld parts which could not be handled in the forge by reason of their size, etc.

Both oxy-acetylene and electric welding processes consist of running molten metal into the joint, and it is a process not confined to iron and steel, nor is the metal used in the weld always iron. Oxy-acetylene welding is used more by agricultural machine repairers, mainly because the plant is self-contained and reasonably portable, so that when necessary the complete outfit may be taken into the field and a sound repair job done with the minimum of delay.

The equipment comprises two strong cylinders, one containing oxygen and the other acetylene gas. Each cylinder has a pressure gauge and a valve which regulates the flow. Good work can only be achieved if the welding nozzles are kept clean, and the nozzles so adjusted that an equal amount of each gas is being burned.

The Repair and Building-up of Worn Parts by Welding

With replacements still in short supply and expensive, the welder must make the best possible use of his equipment for rebuilding worn parts and, where possible, apply wear-resisting facings in order to prevent wear. Machinery parts are often scrapped because of wear at some point, whereas a few minutes' application of the welding flame with a suitable welding rod would deposit enough metal to make good the wear and enable the part to be used again.

The welding material suppliers list about half a dozen welding rods which can be used for this work, but, to begin with, the range of steel rods can be limited to a $3\frac{1}{2}$ per cent. nickel steel and to a wear-resisting alloy steel. The former rod provides a deposit which is easily filed but is a little tougher than ordinary mild steel. The wear-resisting rod usually contains manganese and chromium, and the deposit is, therefore, tough and wear-resisting, and is best finished by grinding or by hammering to shape. Bronze welding rods are very useful for building up many worn parts, owing to the ease with which the deposit can be filed or machined ; a manganese or nickel-bronze rod gives the toughest deposits.

Building up worn parts should not be confused with hard-surfacing (or with hard-facing), which is a different procedure altogether.

Hard-facing materials are excellent for preventing wear, but are expensive and need to be deposited economically ; therefore it is usually best to apply hard facings to new parts where the deposit can be thin. Furthermore, the deposit can only be shaped by grinding—it must not be hammered. There are many applications where hard facings *can* be applied to reclaiming worn parts, but the above considerations must be taken into account. Several makes and types of hard-facing rods are available ; for most agricultural purposes an iron-based rod would be quite satisfactory.

For rebuilding worn iron castings, only cast-iron welding rods or bronze should be used. Cast iron can, of course, be deposited on to steel, and if it is chilled a very hard deposit will result.

Surface Fusion

The $3\frac{1}{2}$ per cent. nickel steel rod is deposited by the ordinary fusion-welding, neutral-flame procedure, and the alloy-steel rod is deposited with the excess acetylene-flame sweating technique (known as surface fusion) (see Fig. 27). With this technique the surface to be built up is heated with the carbonizing flame until—through the welding goggles—it is seen to glisten or sweat. The surface is then ready for the deposit of weld metal. It is important to deposit only on the sweating surface and not to melt the surface, otherwise the wear-resisting characteristics of the rod metal will

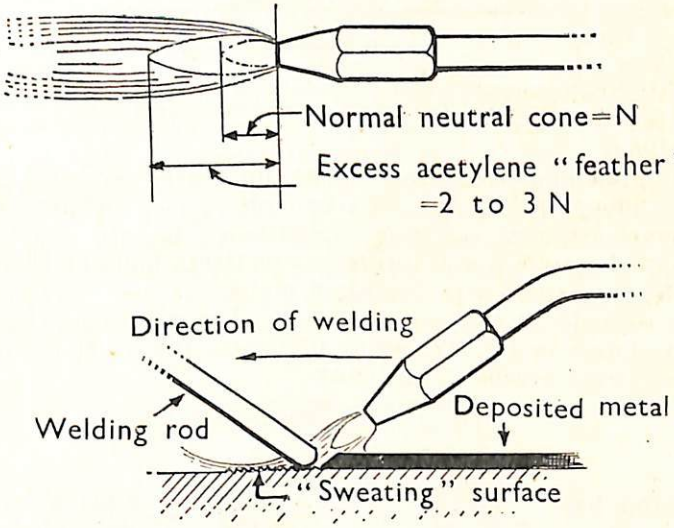


Fig. 27. Diagrams showing the excess acetylene flame sweating technique for depositing alloy steel rods.

be considerably modified. Bronze is, of course, deposited in the normal way without melting the base metal.

Surfaces to be rebuilt should be clean and free from paint, oxide, oil, grease or other matter which might interfere with the efficiency of the bond between the deposit metal and the worn surface, or cause porosity of the deposit. In order to ensure a clean depositing surface, it is usually necessary to machine or grind, especially for the deposition of bronze and when the surface-fusion technique is employed. The surface of shafts should be carefully inspected for cracks or other defects, which might cause failure after rebuilding.

When it is necessary to build up a point or edge, which has been entirely worn or broken away, copper backing plates may be used as a mould, or support, for the deposit metal. Fig. 28 illustrates a method often employed for building up worn excavator-bucket edges or ploughshare edges. Carbon plates may be used in the same way for bronze surfacing applications. In case of excessive wear of steel parts it is not usually economical to build up the whole of the worn portion with deposited metal ; it may, however, be possible to weld an entirely new piece of metal on to the worn edge, as shown in Fig. 29, which illustrates the usual method of rebuilding worn crawler-track units.

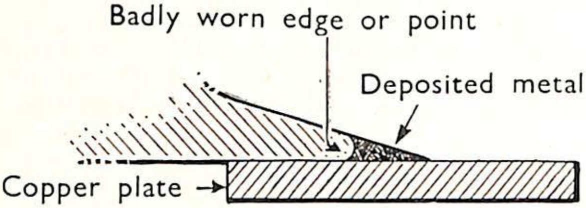


Fig. 28. Use of copper mould plate for controlling weld metal when building up a worn point or edge.

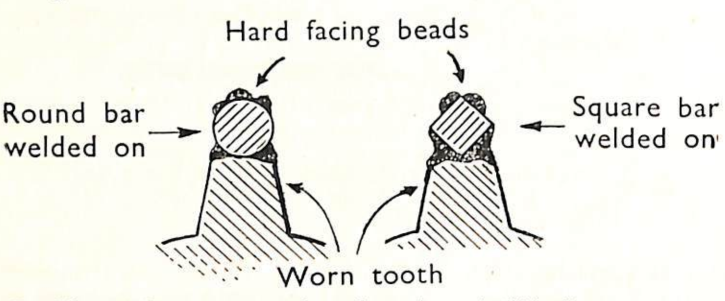


Fig. 29. Welding on a new piece of metal to rebuild badly worn edges.

Large shafts—e.g., roller shafts—should be preheated before commencing to weld, thus reducing distortion, saving welding gases and reducing the time necessary to make the deposit. In some cases a helper with another blowpipe can keep the job hot while welding is in progress. It is sometimes possible to localize the heat and avoid distortion by partially immersing the part in water. This may be done in the case of aluminium castings, or for bronze depositing on iron castings, or for building up ends of valve spindles, tappets, etc.

As far as possible, arrange for the depositing surface to be horizontal or—as with welding—it may be slightly inclined, to allow welding upwards, thus reducing the tendency for deposit metal to flow forward out of control. When building up small narrow deposits, such as gear teeth, splines, etc., do not attempt to deposit too much metal in one run. It may be necessary to deposit several runs in order to build up to the desired depth, but it is easier to control the molten metal in small runs than it is in a heavy run, which, moreover, often leads to the deposition of more metal than is necessary. When several runs are deposited care must always be taken to see that each run is thoroughly fused with the previous one. Incidentally, with badly worn splines or shaft ends, it is sometimes possible to cut off the worn end and weld on a less worn similar part from a discarded shaft.

Large surfaces may be covered by laying down a series of parallel beads, or runs, of weld metal; no attempt should be made to flow the weld metal over large areas, otherwise lack of bond between weld metal and base metal is sure to result. Beads should not be laid side by side, as shown at A, Fig. 30, but the centre of each bead after the first should be over the edge of the previous bead, as shown at B. In this way it is possible to secure a reasonably uniform surface which can be finished with the removal of the minimum of weld metal. This applies specially to the building-up of shafts and to the depositing of bronze on ferrous metals with the non-fusion technique.

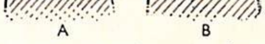


Fig. 30. Building up large surfaces with weld metal. The beads should not be laid side by side as at A, but overlapped as shown at B.

In building up worn portions of shafts, do not start at one place on the shaft and continue to deposit metal until the whole surface is covered. The usual method is to lay down beads of weld metal parallel to the axis of the shaft, that is, in line with the centre line. After laying down the first run, turn the shaft 180° and lay down the second bead on the opposite side to the first run. After completing the second run, turn the shaft 90° and lay down the third bead between first and second; then lay down the fourth bead opposite the third, and so on, as shown in Fig. 31, always placing each run opposite the previous one. In this way the heat is applied to the shaft uniformly and minimizes any tendency to distortion. When completed, the built-up portion should be reheated and smoothed by hammering and then allowed to cool down slowly and uniformly.

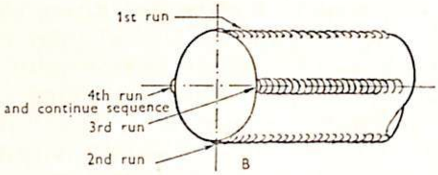


Fig. 31. Sequence for building up worn portions of shafts. Thus, heat is applied uniformly and distortion risks minimized.

Castings

No special procedure is required for building up worn or missing parts of castings. Ordinary cast-iron welding rods or bronze rods may be used in conjunction with the welding techniques and general procedure previously described. When using cast-iron rods, the super, or high-silicon, type is generally preferable if the built-up surface is required to be soft and readily machinable. Bronze may be used where there is no tendency to abrasion and where a good bearing or non-rusting surface is desired.

When preparing to build up a casting, the effects of expansion and contraction and the necessity for pre-heating should be reviewed just as carefully as they should be for repairing fractures. The heat application may create sufficient local expansion to stress or distort other parts of the casting ; moreover, the cooling shrinkage of the weld metal may cause distortion or cracking of the deposit. Even if there is little or no risk of distortion, pre-heating—especially on thick sections—will economize in welding gases and reduce the time needed for the operation. Cool slowly after welding. When building up worn holes or edges, broken lugs or flanges, it is useful to employ carbon or copper plates, rods or carbon paste for moulding the deposit metal, and thus reducing the amount of shaping subsequently required.

Bronze Depositing

As with bronze welding, efficient tinning is important before any attempt is made to build up to the full thickness required, and care must be taken to ensure that molten bronze does not run on to untinned surfaces. On steel, tinning proceeds ahead of the deposit more or less automatically, but on cast iron the welder must ensure that he actually tins the surface ahead of the bronze deposit. The flame should be slightly oxidizing. This ensures a better bond between the bronze and the base metal, prevents "fuming" of the zinc, and makes for better control of the molten metal. A bronze-welding flux is necessary in order to facilitate "tinning."

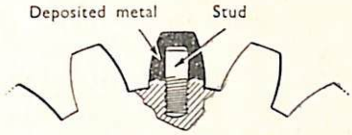


Fig. 32. Method of reinforcing a bronze rebuilt tooth by "studding."

Bronze welding is often used for rebuilding worn, chipped or broken teeth of cast-iron gears. The bronze may be deposited on to the worn or broken surface, but if the surface is dirty it should be cleaned and ground. For rebuilding complete teeth, many welders prefer to reinforce the deposited metal by drilling and tapping the broken surface (after cleaning it) and inserting several studs, as shown in Fig. 32. The studs should neither be inserted on one centre line nor all to the same depth. The tops of the studs should be filed off to allow for the shape of the tooth and to ensure that the stud will be entirely covered when the deposited metal is dressed to shape. Any sharp corners should be rounded off. When depositing, care must be taken to avoid overheating the studs, otherwise the bronze will not adhere. However, studding is not essential, and, especially for small teeth, many welders rely entirely on the strength of the deposited metal alone. For smoothing and compressing the deposit—e.g., on shafts—bronze deposits may be hammer-forged while hot.

Some typical rebuilds, using $3\frac{1}{2}$ *per cent. nickel steel*, are shafts, axles, cams, steel gear teeth, splines, ratchets, holes, etc. With *wear-resisting steel*: Chains, bucket edges, ditcher teeth, holes, hitch pins, cable rollers, shackles, combine shafts, etc.; and with *bronze*: Pump shafts, cast-iron gear teeth, bearings, pump plungers, valve seats, ball-and roller-bearing seatings, etc.

Hard Surfacing

The chief characteristic of the deposit produced by hard-surfacing rods is extreme hardness (500–700 Brinell), and, therefore, resistance to severe abrasion, as previously mentioned. This type of surfacing metal should be used for protecting parts subjected to excessive wear rather than in the surfacing of worn parts. Owing to their comparatively high cost, it is essential to apply hard-surfacing rods economically, otherwise the cost of application may outweigh the advantages gained.

When the hard-facing of badly worn parts is contemplated, the worn surface should first be rebuilt within 1/16 in. to 3/32 in. of finished size (using either a wear-resisting or high-tensile type of welding rod). The rebuilt surface is then hard-faced, thus economizing in expensive hard-facing metal. The excess acetylene flame surface-sweating technique (shown in Fig. 27) must be used for depositing in order to avoid diluting the hard-facing deposit with base metal, which would, of course, reduce its hardness. There is no need to use an excessive amount of acetylene in the flame, as this has no influence on the hardness of the deposit. The total length of the acetylene "feather" should not exceed two to three times the length of the normal neutral cone.

Hard-facing metals are best applied to edges, corners or points where wear is exceptionally heavy. Generally speaking, it is not advisable to attempt to cover large surfaces completely : if a large surface needs protection, this is most economically achieved by laying down independent beads of metal. Slow cooling is essential in order to avoid cracks and internal stresses. Small parts should be dropped into a box of lime, ashes or other heat-insulating material. Large parts should be protected from draughts—e.g., covered with sand or sacking Hard facings should not be quenched in order to increase their hardness.

For most earth-working applications hard facings may be put into service "as deposited"—there is no need to grind them smooth or sharp. Whenever possible arrange the hard facing on a cutting edge, so that any wear that takes place has a self-sharpening effect : for example, assuming the edge shown in Fig. 33 to be moving through soil in the direction of the arrow, A indicates the best position for the hard-facing deposit. It protects the underlying softer metal but allows a certain amount of wear to take place at B, thus keeping the point C sharp. If the whole edge were coated, as at D, the point would gradually become rounded or bull-nosed, thus decreasing its sharpness and increasing the power required to operate the implement.

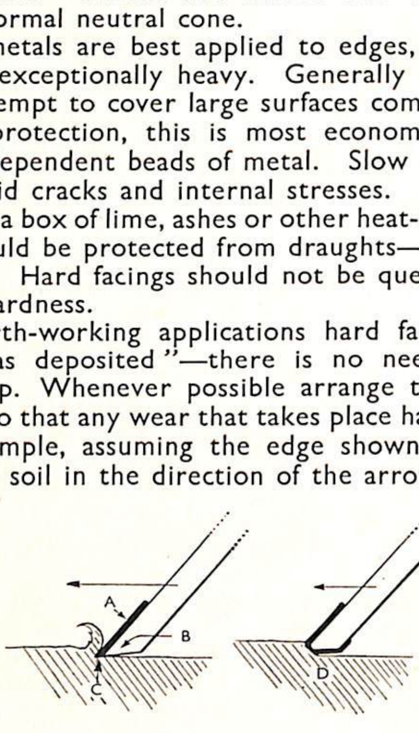
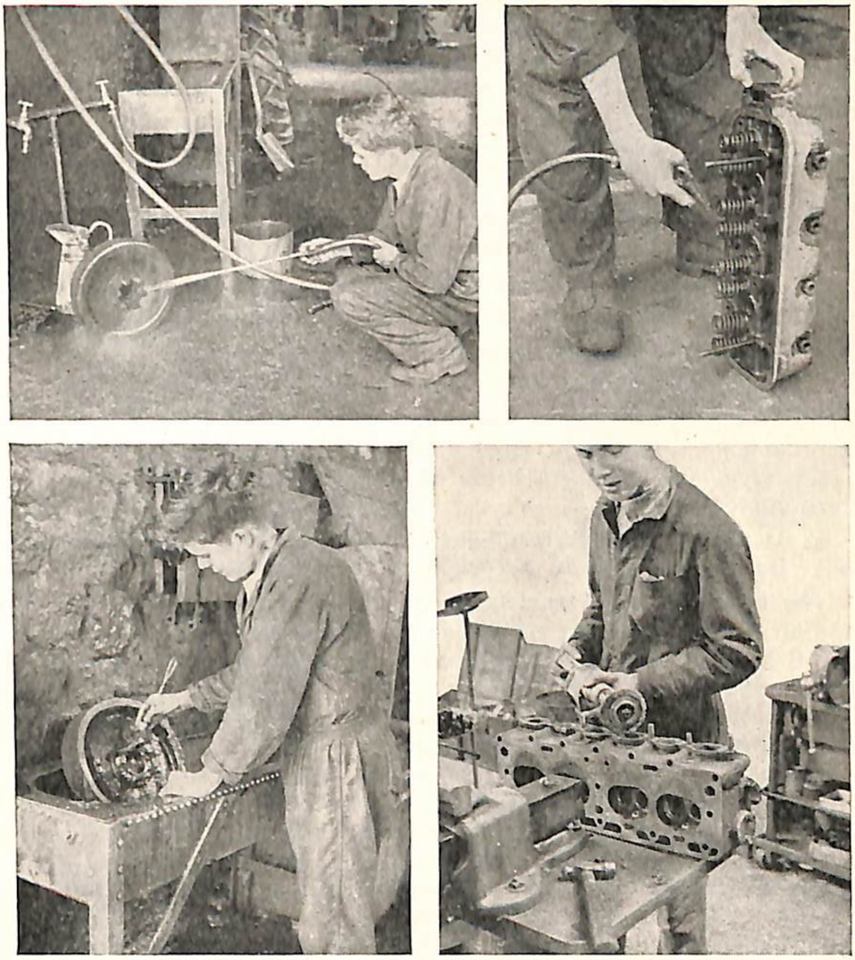


Fig. 33. Effect of hard facing on one edge A only allows wear at B and thus keeps point C sharp. Applying a coating as at D results in a rounded point.

Some good agricultural facing applications are : Steel ploughshares, cultivator points, subsoiler tines, coulters, tractor track lugs and other track parts, parts of mould boards, hammer-mill beaters, ditcher teeth, hoe and shovel edges, etc.



METHODS OF CLEANING PREPARATORY TO REPAIR

Before undertaking any repair work it is essential that all dirt and grease should be removed. This series of photographs shows the more obvious method of cleaning that should be at hand in every well-equipped workshop. (Top left)—A high-pressure jet from the water hose. (Top right)—Compressed air for drying and removing dust and small particles of metal. (Bottom left)—Paraffin bath. (Bottom right)—Wire brush mounted on an electric drill. For larger workshops high-pressure cleaners, producing a spray of hot water, soap and steam, are also available.

Reclaiming Ploughshares

The series of pictures (Fig. 34 on the opposite page) shows a successful method of re-tipping ploughshares by welding tablets cut from scrap spring steel to the share point. The complete procedure by which the new point is fabricated is as follows :—

1. Cut two tablets from scrap car springs.

2. Weld smaller tablet to upper surface of share, offsetting to give land suction.

Arc welding.—Use non-machinable cast-iron electrodes, 10 gauge.
Gas welding.—Use mild-steel or cast-iron rods

3. Heat to cherry red and forge to shape, giving slight twist to bring nose parallel to sole of share. Forge second tablet to shape.

4. Weld larger tablet to sole of share to protrude some ¼ in. to ½ in. beyond upper tablet. Use the same rods as for 2.

5. Weld sides of tablets together.

Arc welding.—Hard-surfacing electrode.

Gas welding.—Wear-resisting, 3½ per cent. nickel rod or high-carbon steel.

6. Re-heat nose thus formed to cherry red and *leave to cool in air. Do not quench. Do not cover with ashes.*

The modern spring steel used for car springs, etc., is both self- and air-hardening. Left to cool in air from cherry red, a figure of 560 Brinell hardness is attained, which is nearly three times harder than a chilled cast-iron share.

Arc welding.—By using a hard-surfacing type of electrode, a figure of 600 Brinell can be attained on the nose.

Gas welding.—Both wear-resisting and 3½ per cent. nickel welding rods, if forged at cherry-red heat, will both forge and air-harden, and although not as hard as the electrodes noted above, still give a very good degree of wear resistance.

The procedure described is designed to give the best welding sequence, bearing in mind that each worn share has to have its point individually set by the smith in the forge fire to allow for differences in wear and to repair the correct land and furrow-wall suction.

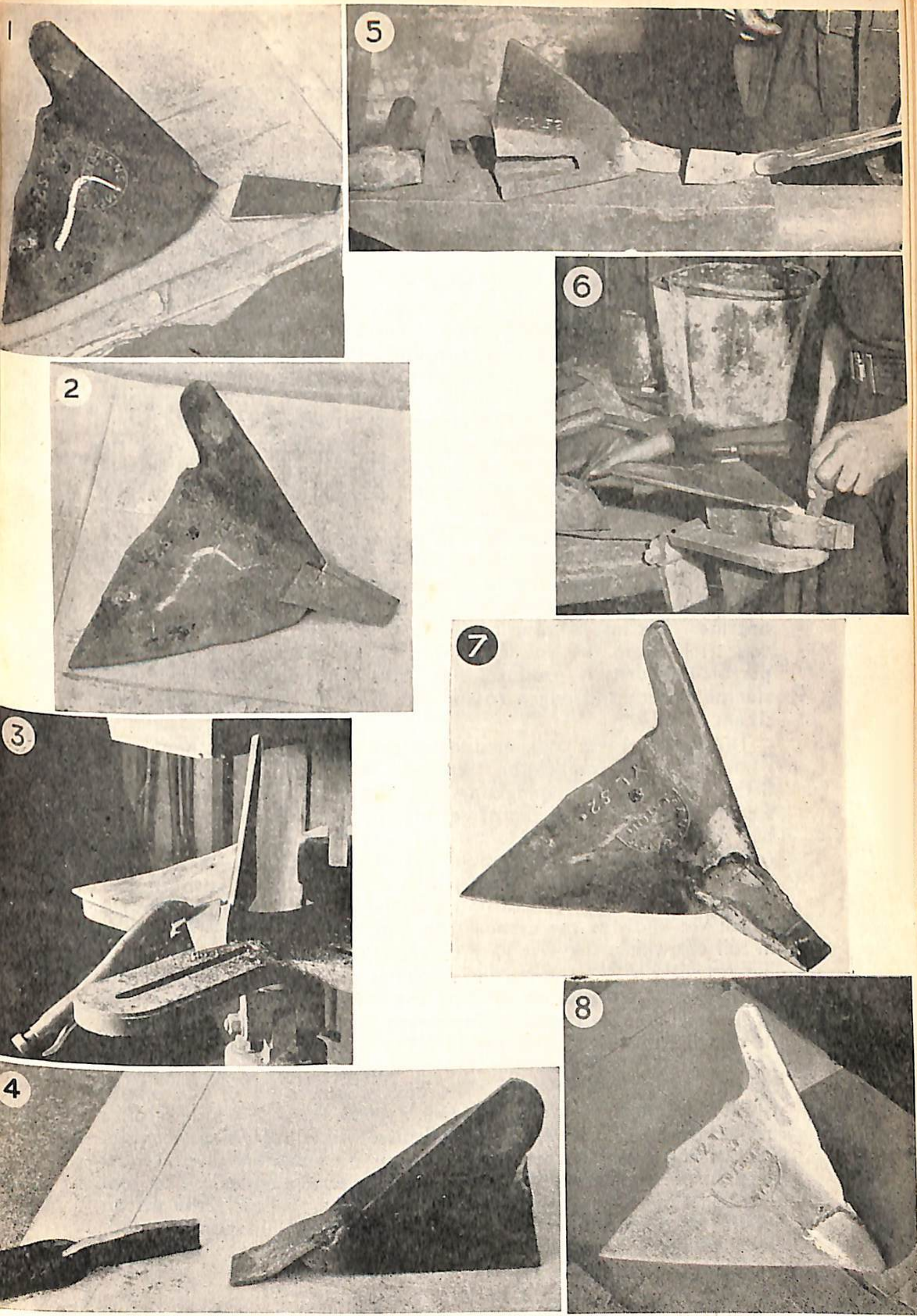


Fig. 34. A successful method of re-tipping ploughshares with scrap spring steel.

VI

PETROL ENGINES

FOR the benefit of those who are not familiar with internal combustion engines, it is necessary to say a few words on their principles and construction. Years ago tractors used to be steam-driven, and the fuel was consumed in a firebox to raise steam. When the steam had been compressed to the right amount, it was passed along a pipe into a cylinder, and the steam drove the piston towards the open end. The piston was attached to a rod which pushed on to a cranked shaft, and on the ends of the shaft were the road wheels. All this is, of course, elementary, but the petrol, vaporizing oil and Diesel engines are simply a development of this method of obtaining power.

To begin with, the fuel used in petrol engines is a refined form of mineral oil, and it was chosen partly because huge supplies were obtainable at a comparatively low cost, and partly because the type of engine which used it was less cumbersome and far less bother to operate. But instead of using the fuel to produce steam, the liquid was itself made to produce power direct, simply because when petroleum burns it produces hot gases which expand with considerable force and which to some extent may be compared with steam.

Thus the fuel was consumed inside the actual cylinder, hence the name " internal combustion " engine. Although such engines are fitted with pistons, connecting-rods and crankshafts just as in a steam engine, the problem of getting the petrol into the cylinders had to be overcome. Liquid fuel was completely unsuccessful (remember we are talking about petrol engines) until it was split up into a very fine mist and then thoroughly mixed with the air in the cylinder. This necessitated a mixing and spraying apparatus which we know as the carburetter, and which has been described in full elsewhere. It was easy to get the spray into the cylinder, but less easy to get the burned gases out of it when they had done their work, and because of this, the " four-stroke " engine was produced. In this engine a downward stroke of the piston sucks in the mixture of air and petrol. The upward stroke then compresses it—for only by doing this can adequate power be produced by the burning of the fuel. The next downstroke of the piston resulted from the burning of the fuel, and the last of the four strokes utilizes the upward movement of the piston to expel the spent gases.

Thus the internal combustion engine necessitated several new departures from the methods used in steam engines. The fuel had to be ignited just at the right time, for if too early the piston would be forced down before it had achieved full compression, and would consequently run backwards for a second or two. If the fuel was ignited too late, then the best part of its power would be lost, so some form of apparatus had to be designed that would set the fuel burning exactly at the right moment. It was thus that the magneto was made.

To enable the fuel mixture to enter the cylinder and the spent gases to leave it, valves are needed, and these not only have to open and shut at exactly the right time, but they must be made of material that will stand up to the heat of combustion. It was because of all these things that the evolution of the modern tractor engine took such a long time to reach its present standard of efficiency.

Other internal combustion engines were made to give a firing stroke every time the piston reaches the top of its stroke, hence the " two-stroke." In this engine there have to be the same four stages as in the four-stroke—induction, compression, combustion and exhaustion, but they are so arranged that the fuel passes not into the cylinder, but into the crankcase. As the piston descends (of course on its power stroke) the underside of the piston pushes the mixture up through a channel, or " port," which leads to the cylinder itself. Thus on that one movement of the piston we have the power stroke and the flowing-in of the new mixture, which, incidentally, pushes out the spent gases. This type of two-stroke engine (for there are others) has a deflector on the piston top which guides the new mixture to the top of the cylinder, thus getting round the back of the exhaust gases and so making for better " scavenging," as it is called.

It should not be imagined that the modern internal combustion engine developed exactly along the lines stated, for although an engine of this type had to have all the components mentioned, they were exceptionally crude. They were, moreover, made to operate on the only grade of petrol then made, and this was considerably less effective for the purpose than the fuels of to-day.

Great strides have been made in metallurgy, so that the modern tractor engine develops much more power for its weight than any of the older machines ; it is far more reliable, and has a much longer life. Methods of construction, too, have altered so that (at any rate in normal times) it is possible to obtain a replacement part that really fits.

So the present internal combustion engine, although basically the same in principle as that of 50 years ago, is enormously improved. Cylinder heads, for example, are practically all detachable, making for easy servicing, and within limits a choice of compression ratios.

When a piston is at the bottom of the cylinder, the cylinder has a certain capacity, which is usually measured in cubic centimetres, but sometimes in cubic inches. As we have seen, this cylinder is filled with the air/petrol mixture, which, when the piston rises, is compressed. The degree of compression, which is commonly referred to as the compression ratio, plays a most important part in the efficiency of the engine, and it must be understood that the compression ratio is by no means the same in all engines. Up to a certain point, the higher the compression ratio the more power one obtains from a given charge of mixture, but not all fuels will stand high compression. It is the compression ratio which determines the rate at which the fuel burns, and normally this should be (for petrol) approximately 250 ft. per second. Now, if the compression is raised, the rate of burning increases too, and there may come a time when the mixture burns so rapidly that it almost explodes. Such a state of affairs is like hammering on the top of a piston, whereas the real aim is to push it down gradually. Thus too high a burning rate results in detonation, which may punch a hole clean through a piston.

Paraffin engines need a lower compression rate than those running on petrol.

The Parts of an Internal Combustion Engine

Cylinders.—An iron casting comprising a block of cylinders open at both ends. The lower part of the casting is machined to house the upper halves of the crankshaft bearings.

The casting includes a water jacket for cooling.

Cylinders are machined from cast iron or they may have steel liners inserted, these being renewable. The internal diameter of a cylinder is called the bore, and the distance the piston moves up and down is called the stroke.

Cylinder Head.—Cast iron or aluminium casting forming a cover to the cylinders. The head is bolted to the cylinder block, a copper and asbestos joint forming a seal. Cylinder heads also have a water jacket, the openings of which coincide with those in the top face of the cylinder block to ensure circulation.

The head contains valves, and holes for sparking plugs are often placed in the head.

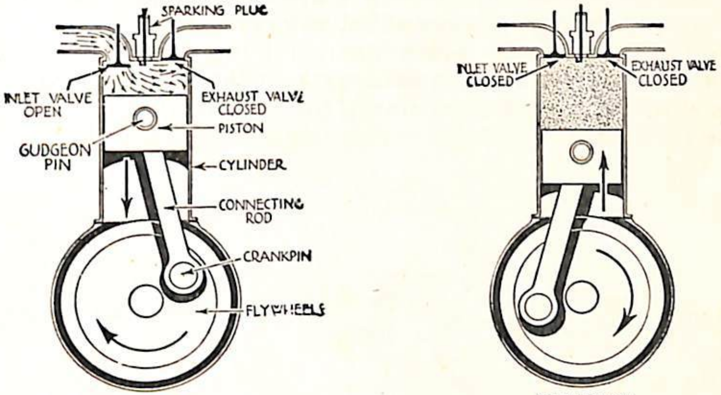
Pistons.—Hollow castings of iron or aluminium alloy. The piston is a sliding fit in the cylinder, but rings of cast iron are fitted to make a gas- and oil-tight seal. The rings fit into narrow grooves machined round the outside of the piston. Rings are split and opened slightly to give requisite contact with cylinder wall. The number of rings fitted varies, but there are usually three per piston. A hollow pin is mounted inside the piston and secured in position. This pin is a pivot for the connecting-rod "small-end," and is known as a "gudgeon-pin."

Connecting-rod.—As its name suggests, it connects—in this case the piston with the crankshaft. The bearing at the lower (and larger) end of the connecting-rod is called the "big-end" bearing. The actual bearing surface is generally of a white-metal alloy, and is made in two halves.

Crankcase and bearings.—The cylinders are cast in one with the upper half of the crankcase which carries bearings for the crankshaft and flywheel. As with big-ends, the crankshaft bearings are made in two halves. That part of the crankshaft which fits inside a bearing, whether big-end or main, is called the journal.

Crankshaft.—This needs no explanation other than an illustration (see Fig. 35).

THE FOUR-STROKE CYCLE

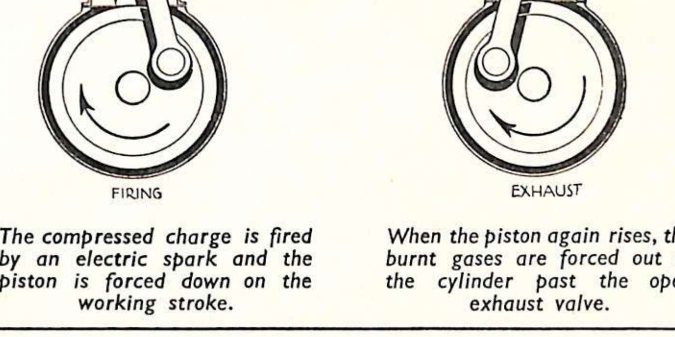


INDUCTION

On the induction stroke the piston descends, drawing in an explosive charge through the inlet valve.

COMPRESSION

The piston then rises and compresses the charge in the cylinder head; both valves are closed.



FIRING

The compressed charge is fired by an electric spark and the piston is forced down on the working stroke.

EXHAUST

When the piston again rises, the burnt gases are forced out of the cylinder past the open exhaust valve.

Fig. 35

Valves.—These are usually of a mushroom shape, comprising a head and a stem. The valve stem slides up and down a guide and is raised from its seating by a rocker arm operated by a push-rod, which is in turn moved by a cam on a camshaft. Interposed between the cam and the push-rod is a tappet. When the valves are in the cylinder block (i.e., side valves) the tappets are adjustable, but on overhead-valve engines adjustment is at the upper end of the push-rod.

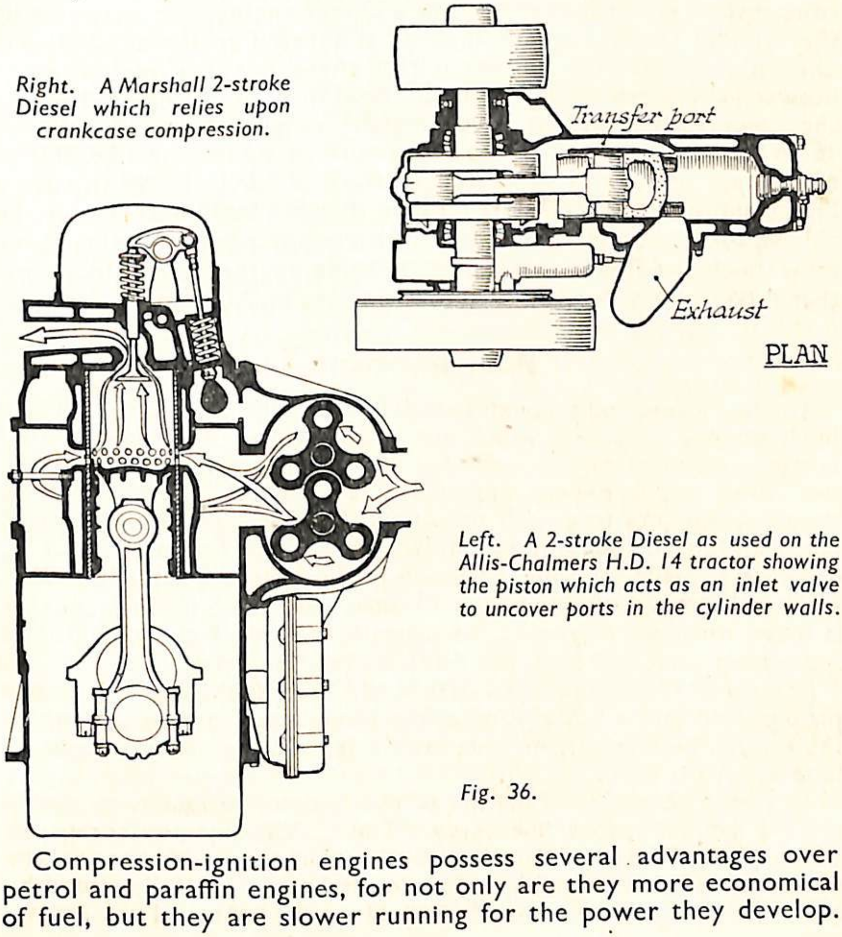
Camshaft.—A shaft fitted with shaped projections called cams. It is revolved through gearing at half the crankshaft speed.

Governor.—A device which limits the maximum r.p.m. of an engine. Governors are operated by centrifugal force, and consist of weights, which move outwards from their axis and close the engine throttle.

VII

DIESEL ENGINES

A type of engine that is becoming more and more popular for commercial-vehicle and tractor use is that commonly known as the Diesel, although a more descriptive name is "compression ignition." In a petrol or paraffin engine a mixture of fuel and air is compressed in the cylinders and ignited by an externally-produced spark. A compression-ignition engine, on the other hand, compresses a charge of air only, the fuel being injected at a still higher pressure when the piston is at or near the top of the compression stroke. No separate ignition system is needed because air which is compressed rapidly becomes hot—sufficiently hot to ignite the fuel injected into it.



Right. A Marshall 2-stroke Diesel which relies upon crankcase compression.

Left. A 2-stroke Diesel as used on the Allis-Chalmers H.D. 14 tractor showing the piston which acts as an inlet valve to uncover ports in the cylinder walls.

Fig. 36.

Compression-ignition engines possess several advantages over petrol and paraffin engines, for not only are they more economical of fuel, but they are slower running for the power they develop.

There is accordingly less wear and longer life. The chief disadvantage of the Diesel is that it is more costly to buy.

When it is realized that the speed and power is regulated by the quantity of oil used at each injection, and that a cylinder of 4 ins. or so in diameter requires a spot of oil half the size of a grain of rice (and this at the maximum revolutions a minute), it is clear that the metering device, or fuel pump, must be a precision instrument made to fine limits.

Compression Ratios

Diesel engines are made for two-stroke and four-stroke cycles, the latter being the more commonly employed, although the popular Field Marshall tractor is a two-stroke. As both the two- and four-stroke petrol engines have been described in detail, there is no need to repeat the principles here, except to say that crankcase compression is not always used in a Diesel engine, the air entering the cylinder through a port directly connected to the atmosphere. One other point of difference is that there is much less clearance between the piston top and cylinder head in a Diesel engine, because the compression ratio is much higher, ranging from 12 to 1 to 16 to 1, or even more, giving a pressure of something like 500 to 600 lb. per sq. in. and an air temperature of 1,000° F. With such a high compression ratio it will be seen that the fuel injector must be able to force the fuel through at even greater pressures, this rising to as much as 6,000 lb. per sq. in. on some engines, but seldom less than 1,000. The Marshall injector operates at 2,000 lb.

Fuel Injectors

The fuel is injected through a small hole which splits up the oil into finely-divided particles, which are so necessary to complete combustion. It must be realized that the setting of a fuel pump is a job which needs expert knowledge, so that the farm mechanic should never interfere with the pump, because irreparable damage may result. Fuel pumps not only measure the fuel and inject it, but they provide for some variation in the time the injection takes place, this corresponding to the advance and retard mechanism that is fitted on most magnetos. Automatic timing of the injection is sometimes used, although not often on road vehicles.

In view of the complicated nature of Diesel fuel pumps, it is not proposed to give a description of the pump itself, but to pass on to the nozzle, or injector, for this can be serviced by the mechanic so long as care is used.

As stated above, the function of the injector nozzle is to divide the oil droplet into a fine spray. The C.A.V. injector comprises a strong metal body which is screwed into the cylinder head in the same way as a sparking plug. The nozzle hole is normally closed by a conical plunger valve, which is held on to its seat by a spring.

When the oil pressure from the pump reaches the desired amount —and, of course, this is arranged to coincide with the firing moment —the valve is raised and the oil forced through the nozzle into the engine cylinder.

Fig. 37 shows a C.A.V. injector in section. It will be seen that there is a leak-off tube provided. This is so that any excess of oil which leaks back past the plunger can pass back to the pump suction chamber or to a drain tank. The particular injector shown here has a feeling pin so that the operator can tell if the plunger is working when the engine is running. Various types of nozzle ends are used, but the farm mechanic need not concern himself with these, as the most suitable one is already in the injector when the tractor is delivered.

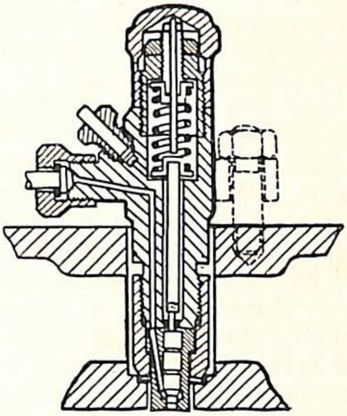


Fig. 37. Section of C.A.V. Injector.

Servicing Diesel Injectors

With regard to servicing, this should be confined to keeping the nozzle and the plunger free of carbon, and no interference with the plunger spring or its adjusting screw is advised. Before giving details on injector maintenance, it is necessary to say that absolute cleanliness is essential when handling them, for the smallest piece of dirt will render the work useless. The part of the bench used for the work should be quite clean and for preference have a metal top. The mechanic's hands should be clean, and, because contact with fuel oil has in some instances caused skin trouble, some such preparation as " Rozalex " should be well rubbed into the hands.

Although there are many different designs of injector, we deal here only with those fitted to the Caterpillar, Marshall and Fowler tractors as coming most commonly within the routine of the farm mechanic.

Caterpillar

Before removing an injector or the pump from an engine that is operating irregularly, a simple check may be made to determine which cylinder is not firing properly. With the engine running at a speed that makes the irregularity most pronounced, momentarily loosen the fuel-line nut just above the fuel pump sufficiently to "cut-out" the cylinder. Check each cylinder in the same manner. The object of loosening the nut is to provide an escape for the fuel before it can reach the injector, so if one is found where the loosening of the nut makes no difference on the operation of the engine, that injector is probably at fault, although it may be that that part of the pump supplying it is also faulty. A bad injector will cause irregular running and possibly smoking, whereas hard starting and irregular operation is probably due to the pump.

Clean all dirt and grit from round the injector before removal, then disconnect the fuel injection pipe and the fuel drain pipe and remove the holding-down nut that keeps the valve in place. Turn the injector upside down or to a horizontal position and connect up the fuel pipe again. This is so that the quality of the spray emitted may be seen clearly. Next loosen the fuel line to each of the other injectors to prevent their operation. Start the starting engine, and with the Diesel engine compression release lever in the start position, engage the starter pinion and clutch. If the starting engine is operated slightly above its low idle speed, the Diesel engine will be turned sufficiently fast to insure an accurate check on the spray characteristics of the injector. With the starting engine cranking the Diesel, open the Diesel throttle wide and notice the fuel spray that comes from the injector. If the spray is fine and even and in the form of a mist, then the injector is in good condition.

The fuel-discharge hole in the nozzle end will not clog completely with carbon accumulations, but may under some conditions collect a small amount on the inner diameter of the fuel-discharge opening. If a slightly greater amount of carbon forms on one side of the opening than on the other, the spray will have a tendency to shoot to one side. Often the cleaning of the nozzle hole is all that is necessary to make the injector operate as it should, but it should be replaced if, after cleaning, it shows the following spray characteristics :—

1. Fuel discharged in a solid stream or jet.
2. Fuel spray emitted on one side of the nozzle.

A valve should not be rejected, however, unless it fails to spray properly when the starting engine is operated at full governed speed, for this speed is only about half the slowest speed at which the Diesel is required to run.

When replacing injection valves, the holding-down nut should be drawn down only tight enough to prevent leaks between the injector and its seat.

Marshall

To test the working of the nozzle, remove the fuel pipe and take out the nozzle, reconnecting it so that the nozzle points outwards to the atmosphere. Turn the engine over with the starting handle, with the fuel control lever in the full-speed position. The nozzle should then sharply discharge a fine spray in the form of a cone and without the presence of any solid drops of fuel whatever. No drops should form to any extent on the nozzle end. If carbon is present, soften it by wetting it with clean paraffin or fuel oil and then clean away the deposit. Under no circumstances allow the hand to come into contact with the spray in close proximity to the nozzle as the pressure will cause the oil to penetrate the skin.

Fowler FD3

As with most fuel-pump equipment, the adjustment on the injector system of the Fowler FD 3 is work for specialists, and should not be attempted by ordinary users. If the fuel pump is changed for any reason, it will be necessary to check the timing on the assembly according to the detailed instructions in the handbook.

VIII

TRACTOR FUELS

ONE of the most essential requirements of a tractor is a power unit which burns a cheap fuel without trouble and at the same time provides ample power at low speeds. The liquid fuels in use to-day in the United Kingdom are motor spirit (referred to as gasoline on some makes of tractors, and commonly called petrol), vaporizing oil (which is kerosene distillate, and commonly known as paraffin), and Diesel, or gas, oil. Of these vaporizing oil is by far the most popular, and is used by about 90 per cent. of the tractors in the field to-day.

The difference in taxation on these fuels (motor spirit 9d. per gallon, vaporizing oil 1d. per gallon) has discouraged the development of the petrol engine for tractors, although this fuel undoubtedly has many advantages. It is better for cold starting ; it has a higher thermal efficiency, which means that actually it contains more power ; the consumption in terms of gallonage is lower ; less lubricating oil is needed than in an engine running on vaporizing oil ; and, lastly, petrol gives a better drawbar pull.

The heavy tax is not the only factor which prevents farmers using petrol-driven tractors, for the regulations governing the store of highly-inflammable motor spirit are somewhat exacting, and bulk storage must be in underground containers. Yet even if the tax were removed or considerably reduced, there would still remain the difficulty of converting vaporizing oil tractors to burn petrol. This cannot be done readily, one reason being that vaporizing oil mixture cannot be compressed in engine cylinders beyond a certain pressure without risk of detonation, and this compression ratio is much lower than that used in petrol engines. Thus to convert to petrol might well mean the fitting of new pistons or a new cylinder head, and possibly both, while in the case of the Fordson tractor a new carburetter and a new manifold would also be needed. Nor must it be overlooked that the modern vaporizing-oil tractor invariably has the fuel tank set directly over the engine, so that some of the heat is used to warm up the fuel. Such a procedure might be dangerous with petrol, and in any case the loss of fuel by evaporation would be considerable.

A further point is that we shall not always be confined to using petrol with a low octane value, and with the return of leaded fuels trouble would certainly be experienced, for although leaded fuel is perfectly satisfactory for cars, it is not for tractor and for many commercial vehicle engines.

The effect of seasonal use must also receive some consideration with leaded fuels. For instance, the engine used to drive and operate the combine harvester might not be used for some 40 or more weeks, and unless proper precautions are taken by the operator, a deposit will form inside the cylinders and result in cold corrosion and harm cylinders and valves.

Vaporizing oil possesses the necessary characteristics for internal-combustion engine use, but it has to be converted into a vapour before it reaches the cylinders. In the early 'twenties, burning oil or paraffin was in general use as a tractor fuel. It has a low octane value (less than 20 as compared with the 50 of a vaporizing oil of to-day), and the use of vaporizing oil enabled engine designers to raise the compression ratio slightly. If paraffin were used in present-day engines it would probably detonate.

IX

CARBURATION

THE correct operation of any internal combustion engine depends to a great extent upon the quantity and the quality of the fuel it receives. The term " quality " does not here refer to the superiority or inferiority of the fuel but to the proportion of fuel to air.

A petrol engine requires a mixture of fuel and air in the proportion of 15 parts of air to one part of petrol—in both cases by weight and not by volume. It is the function of the carburetter to produce this mixture, and at the same time to make sure that both air and fuel are thoroughly mixed.

One of the troubles encountered by the designer of a carburetter is that air being a gas and petrol being a liquid, they do not behave in the same way. It is, for instance, a comparatively simple matter to design a carburetter that will give the correct mixture when the engine is running at, say, 500 revolutions a minute. It is equally simple to design a carburetter that will provide the correct proportions for an engine running at 2,000 revolutions a minute. The difficulty comes in producing one which will suit an engine when it is running at higher speeds or at any intermediate, faster, or slower speed.

For this reason the modern carburetter has more than one jet, and is really several carburetters in one. Thus carburetter adjustment is more complex than is generally appreciated, and it is futile to open up this jet and close that one without realizing what the result will be. It is true that often the effect of opening a jet is not immediately apparent, but it will later be revealed by the increased fuel consumption, increased formation of carbon, and eventual loss of power. On the other hand, closing a jet—cutting down the amount of fuel—again upsets the proportion of air to fuel, and may lead to overheating and the burning of the valves.

Mixture Adjustment

It will perhaps be useful to know how this happens, so we will first take the case of too rich a mixture. If the proportion of fuel is too high, the mixture takes longer to burn because of the lack of oxygen. But the time allowed for burning is so short that the exhaust valve opens before it is completed, thus unburned fuel is expelled without doing any work. Moreover, owing to incomplete combustion, the fuel (which contains carbon) forms a sooty deposit inside the cylinder, on the sparking plug and round the valves, so that before long these all become heavily coated. Carbon, if not properly burned, will sometimes become incandescent and so will provide an ignition system of its own so that switching off the magneto does not stop the engine.

The effect of a weak mixture is very different, for with an excess of oxygen we get too much heat and the valves will burn. Ordinarily we have no means on the farm of determining the proportion of air to fuel, and we must therefore rely upon the carburetter maker's recommendations as to the correct amount to open each jet. It sometimes happens, however, that the carburetter has been dismantled by someone who has not observed the position of the needles.

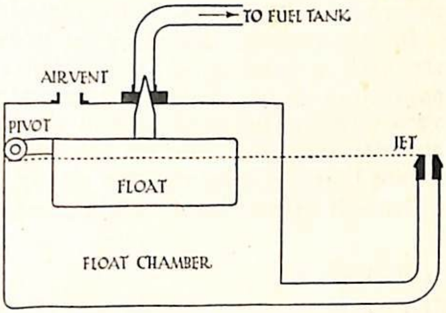


Fig. 38. Drawing shows a pivoted type of carburetter float and explains how the float maintains the right level of fuel in the jet itself as well as in the float chamber. The air vent must be kept free from blockage.

The accompanying diagrams, showing the internal operation of a carburetter, will be useful in making the correct adjustment. It is first necessary to consider the general arrangement of a simple carburetter.

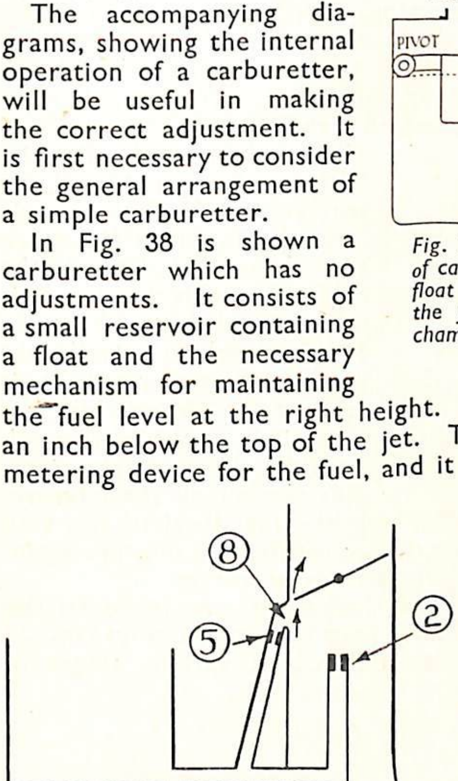


Fig. 39. When the throttle butterfly is shut down the air will rush across the opening to the slow running jet and a fuel/air mixture pass into the engine manifold.

In Fig. 38 is shown a carburetter which has no adjustments. It consists of a small reservoir containing a float and the necessary mechanism for maintaining the fuel level at the right height. This level is just a fraction of an inch below the top of the jet. The jet itself is a measuring or metering device for the fuel, and it allows no more than a certain quantity to pass through it. The fuel will not emerge from the jet by itself, and so the jet is placed in a tube connected at one end via the engine manifold to the cylinders, and at the other end through an air filter to the open air. When a piston descends on its suction stroke, the pressure of air in the manifold is reduced so that atmospheric pressure being greater, air is forced past the jet and into the engine. The insertion of a choke tube increases the depression over the jet and causes petrol to emerge and be carried with the air stream in the form of a fine mist. The butterfly valve, or throttle, controls the amount of air (and consequently fuel) which passes into the induction pipe.

Such a carburetter would be unsatisfactory for general use because when the throttle is nearly closed the air stream would not pass over the jet and no fuel would emerge. To overcome this difficulty, a slow-running jet is fitted, the outlet from it being placed as in Fig. 39. It will be seen here that when the throttle butterfly is shut down, the air will rush across the opening of the slow-running jet as shown by the arrows, and a fuel/air mixture pass into the engine.

It is, however, necessary to provide a mixture which varies in strength according to the requirements of the engine and the conditions under which it is running. With the simple main jet shown in the drawing, it will be appreciated that the greater the air rush over the main jet the bigger the quantity of fuel, and this means that the mixture gets richer and richer. To prevent this a diffuser is fitted, the principle of which is shown in Fig. 40.

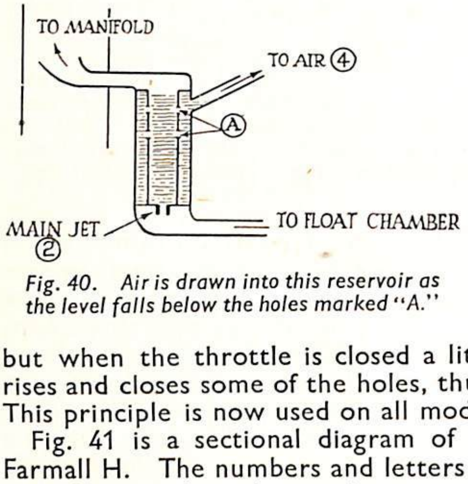


Fig. 40. Air is drawn into this reservoir as the level falls below the holes marked "A."

The main jet is placed at the bottom of a small well, or reservoir, and in the reservoir is a tube in which there are several rows of holes. As the engine speed is increased, it takes petrol from the well, and the level in the well sinks until the first row of holes is uncovered. When this happens air is drawn in through the tube shown on the right, thus weakening the mixture, but when the throttle is closed a little the fuel level in the well rises and closes some of the holes, thus enriching the mixture again. This principle is now used on all modern carburetters.

Fig. 41 is a sectional diagram of the carburetter fitted to the Farmall H. The numbers and letters have been repeated in Figs. 39 and 40, so that the reader can follow the various stages of development.

(1) Choke tube, or venturi.
(2) Main fuel jet.
(3) Main jet discharge nozzle.
(4) Main jet air bleed.
(5) Slow-running, or idling, jet.
(6) Slow-running adjustment needle.
(7) Main jet adjuster.
(8) Idling slot.
(A) Holes in diffuser.
(B) Accelerating well.

The main jet size is such that at full load the correct proportion of fuel to air is obtained, and the main jet adjustment reduces this amount to that required for economical operation for certain conditions of use.

Two adjustments are provided, these being the slow-running needle and the main jet, and it should be appreciated by now that any faulty adjustment will either give too rich a mixture and so waste fuel, or too lean a mixture and result in bad running. Because all engines are not alike in their fuel requirements, it is not possible to say that if each of the adjusting screws is opened so many turns that setting will be right in every case, so the reader should consult the tractor manufacturer's instruction book where possible. If no such book is available, just remember that the main jet, when fully open, is designed for a full working load, so something less than, but near to, that point should be sufficient to get the engine warmed up, when a finer adjustment can be made. The same principle applies to the slow-running jet.

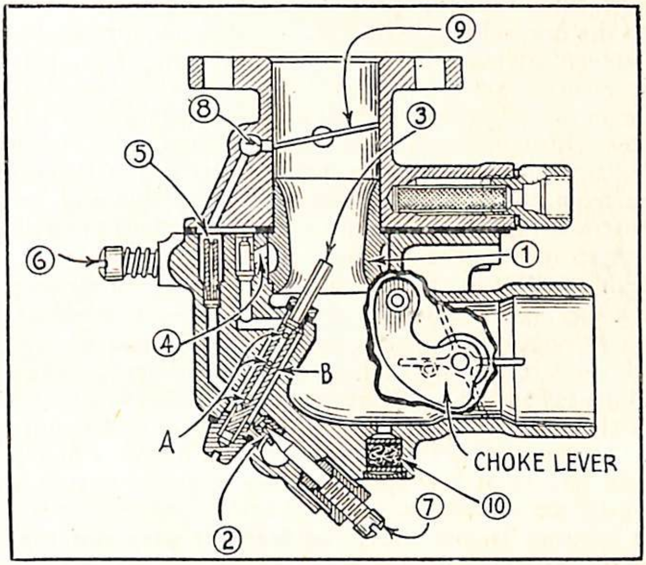


Fig. 41. SECTIONAL DIAGRAM OF CARBURETTER.

1. Venturi or choke tube. 2. Main fuel jet. 3. Discharge nozzle. 4. Main jet air bleed. 5. Slow running jet. 6. Slow running adjustment needle. 7. Main jet adjuster. 8. Slow running slot. A. Holes in diffuser. B. Accelerating well.

Many carburetters, particularly those on cars and on many stationary engines, have but one adjustment—that of the slow-running jet—and even this is confined not to any alteration of the jet size but to the amount of air drawn in. Any alteration needed to the main jet is, in these carburetters, a matter of fitting another jet or another choke tube. A slightly smaller tube enriches the mixture, and a larger one weakens it.

X

VAPORIZERS

TRACTORS which are equipped for running on vaporizing oil have a device fitted which is called a vaporizer to convert the heavier liquid fuel into gaseous form. Vaporizers will not, however, atomize the cold fuel just as will a carburetter, so that such engines use petrol—and a carburetter—for starting, the change-over taking place as soon as the engine is hot enough to run on vaporizing oil. This process takes from 10 to 15 mins. in most engines.

Generally speaking, the best way to vaporize a heavy fuel is to heat it, and a common method of doing this is to create a hot spot in the inlet manifold by diverting some of the exhaust gases on to it. On the Fordson tractor, for example, a large vaporizing plate is bolted to the hot exhaust manifold, the plate having sundry channels through which the mixture passes. The oil comes from the tank into a regulator valve, and thence into a float chamber, in which the fuel level is maintained in much the same manner as in a carburetter. It then goes through an adjustable needle valve to a small jet behind the float chamber, and here it is met by a stream of air coming from a by-pass from the air pipe. The mixture of air and fuel is then sucked into the passage in the hot vaporizing plate described above. As this plate is hot, the mixture is vaporized, and passes into a chamber in which it encounters a further supply of air coming from the air cleaner. It is essential that the proportion of air and fuel is correctly proportioned, so a control needle and a priming valve are fitted, the latter being controlled from the dash. The vaporizer plate and float chamber are illustrated in Fig. 42. Too rich a mixture increases the carbon formation in the cylinders and results in overheating. In addition to this, the fuel consumption is heavy, and the engine will misfire at low speeds. Too weak a mixture will cause backfiring in the vaporizer.

A rich mixture is, however, required for easy starting, and the dash control restricts the flow of air, so causing the engine to obtain a larger proportion of fuel. Incidentally, the choke control should not be pulled out when the engine is warm, or too rich a mixture will result.

Adjacent to the choke lever is a spring-loaded, vacuum-operated diaphragm, which allows an extra supply of air when the tractor is pulling light loads. As the throttle is opened from its closed position, the depression in the manifold draws the spring-loaded valve in the economizer off its seat, permitting an extra supply of air to reach the vaporizer fuel. But when the throttle is opened still more—according to the power required from the engine—the manifold depression is reduced until it is not enough to raise the valve from its seat, so that the air supply is cut off. No adjustment is necessary on this device, which is fully automatic and set by the manufacturer.

The external adjusting needle controls the admission of fuel to the main jet, thus providing the operator with means of suiting the fuel supply to the load. The best setting is approximately 2¼ turns open, but on light loads it may be found advantageous to screw the needle in a little.

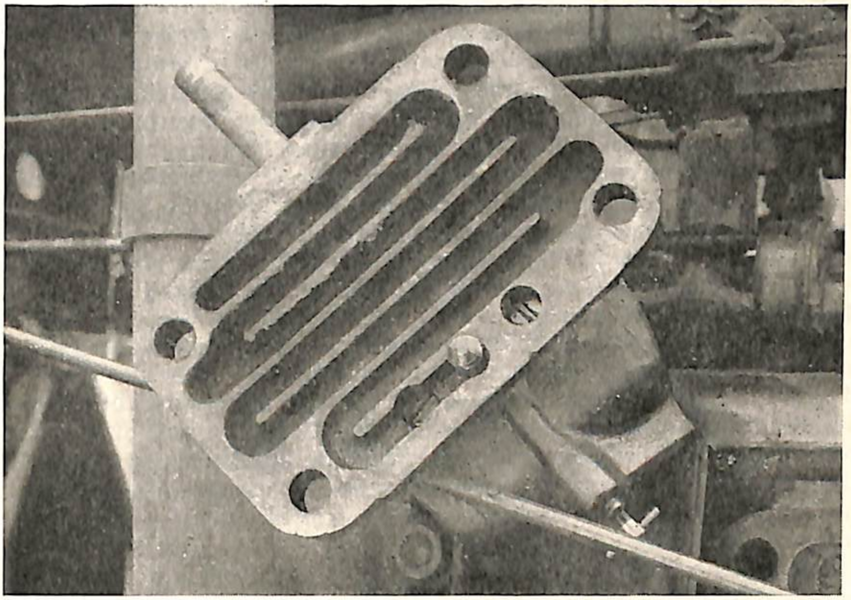


Fig. 42. Float chamber and vaporizing plate on Fordson.

Cleaning the vaporizer plate is a task that must be done when carbon accumulates on it. Disconnect the fuel feed pipe, the manifold shield panel and the four manifold cover studs, when the vaporizer plate can be taken off. A wire brush will soon remove the carbon.

The increase of power and high thermal efficiency of gas oil may lead to rapid development in the future of the Diesel engine. Diesel oil used in tractor engines is tax free, and the success of machines fitted with this form of power has aready been proved for farm work.

Gas oil of good quality should possess certain features that will enable the engine to run smoothly without Diesel "knock," start easier and develop its maximum rated horse-power with a clear exhaust. The pressure-ignition engine is entirely dependent upon satisfactory injection and compression.

Allowing for some of the difficulties of starting in cold weather, this form of power has distinct advantages.

XI

LUBRICATION

LUBRICATION plays such an important part in the efficiency of a tractor—and, indeed, of any piece of machinery—that it is as well to understand something about oils and the work they do. Their chief function is to reduce friction, for no matter how smooth a piece of metal may be finished, it always has *some* degree of roughness, and if a highly polished piece of metal is placed under a microscope, it is seen that the " smooth " surface is actually jagged. When two such surfaces are pressed together and dragged in opposite directions the minute " teeth " or jagged portions interlock ; the resistance offered by this interlocking is called friction. Although friction is very useful for many purposes, it is not wanted in an engine, because it creates heat and causes wear. It may be argued that if such surfaces continually rub together they are eventually bound to be so smooth that there will be no friction, but should ever this happen, the air pressure on them would be so great that they simply would not slide at all.

The degree of heat caused by two rubbing surfaces is proportional to the pressure between them and also dependent upon the speed of rubbing. If these are carried to excess, the metals will become so hot that either or both will seize solid. Not all metals offer the same resistance to rubbing. Besides having a low degree of friction a modern bearing metal actually acts as a safety valve, for it will melt and run out long before the crankshaft or connecting-rod gets hot enough to seize and snap.

To reduce the friction still further a substance called a lubricant is used, this being a liquid or a semi-solid material interposed between the metals and preventing them from actually touching. There are a good many substances which can be—and are—used as lubricants. For instance, when cutting rubber with a knife, the worker knows that if the blade is made wet it will cut much more easily because the water reduces the friction between the rubber and the knife.

Engine Lubrication

In a tractor engine the revolving parts not only rub together at a high speed, but they are also subjected to considerable heat and pressure, so that the type of lubricant used must be capable of withstanding many things. Nothing better than oil or grease has as yet been found to reduce the friction between metals, but not all oils will stand up to the work, and as far as the inside of an engine is concerned, a grease is useless.

The initial qualities demanded of an engine oil are that it shall be able to resist pressure, resist heat and stay in the bearing. There are many kinds of oil, but those used in internal combustion engines are almost entirely of mineral origin. They are not the " oiliest " of oils, but they are stable under working conditions, and they possess the three qualities mentioned above. Vegetable oils are quite unsatisfactory, and the only one which can be used with any degree of safety is castor oil, which is very expensive and needs blending with other substances.

Causes of Oil Dilution

The majority of tractor engines start up on petrol and change over to vaporizing oil as soon as the engine is sufficiently hot to vaporize the heavier fuel. When any fuel strikes a cool cylinder wall it condenses and runs down the walls, carrying with it the oil with which the piston is lubricated, thus causing high cylinder and piston-ring wear right from the start. By using a free-flowing oil a great deal of this initial wear is prevented. The oil must, moreover, be non-gumming even at freezing temperatures, for more often than not tractors are left in the field over-night or at the most put into a draughty and unheated shed. A thick or gummy oil makes hand-starting more difficult, and if a self-starter is fitted, the strain on the battery may buckle the plates and ruin them.

Tractor engines should be operated at high temperatures—almost at boiling point, in fact—so it is obvious that the oils selected must be able to withstand this high temperature and maintain a constant film of lubricant on all the bearing surfaces. Tractor engines, however, are not always running under load, for when a change of implements or an adjustment has to be made, the engine is shut down to idling speed and consequently cools down somewhat. This results in fuel droplets forming on the cylinder walls and, particularly in an old engine, getting past the pistons and into the crankcase, thus diluting the oil in the sump. Now excessive crankcase dilution makes the oil thin—reduces its viscosity—and it may happen that there is not sufficient reserve of film strength to maintain the bearing in a properly lubricated condition.

Oxidation

Another trouble encountered is the action of oxygen on very hot oil. The oil in a crankcase is constantly being churned up so that the oxygen in the air is being " kneaded " into it. This action, added to the effect of metal particles, dirt and carbon, results in decomposition of the oil which forms a thick mass known as sludge.

As a result of experiments, good quality oils are now treated with chemicals which counteract the effects detailed above. For instance, the addition of a soluble tin compound considerably retards oxidation, and the addition of a chromium compound minimizes the corrosion of the cylinder walls that is caused by the products of combustion. Even so, an oil can resist only a certain amount of fuel dilution, oxidation and contamination by solid particles, so it is imperative that it be renewed at the intervals stated by the manufacturer of the tractor.

Then, too, some tractors need a different oil in the winter from that in the summer. This is because dilution is not so serious in the summer, although, on the other hand, when an engine is running at full power there is a greater risk of the oil thinning because the surfaces with which it comes into contact are hotter. If, therefore, the manufacturer of a tractor recommends a different oil for winter use, he does so with very good reason, and the operator should follow his advice.

So far we have been talking about vaporizing oil engines, but although the petrol engine suffers less from condensation and there is, therefore, less crankcase dilution, other factors must be considered. For instance, a petrol engine has a higher compression ratio than the vaporizing oil engine, and this means a more powerful "explosion" and an additional strain upon the bearings. Moreover, petrol engines usually operate at higher speeds, so that taking everything into consideration, the oxidation tendencies are just as severe, and the same advice is therefore given—use the best-quality oils and keep to the instructions of the tractor maker as regards changing.

Transmission Lubrication

With regard to transmission, this presents a slightly different problem. Tractors have to pull heavy loads, and can do so only through gearing. This means that there must be a considerable reduction of speed between the engine and the rear axle, and this is accomplished by a single worm reduction or by double-reduction spur and bevel gears. Some manufacturers, too, use a single lubrication system for the transmission and the final drive, whilst others separate them and recommend different lubricants. Thus it is not possible to make an oil that is capable of satisfying every requirement, hence different oils are offered for different parts of a tractor.

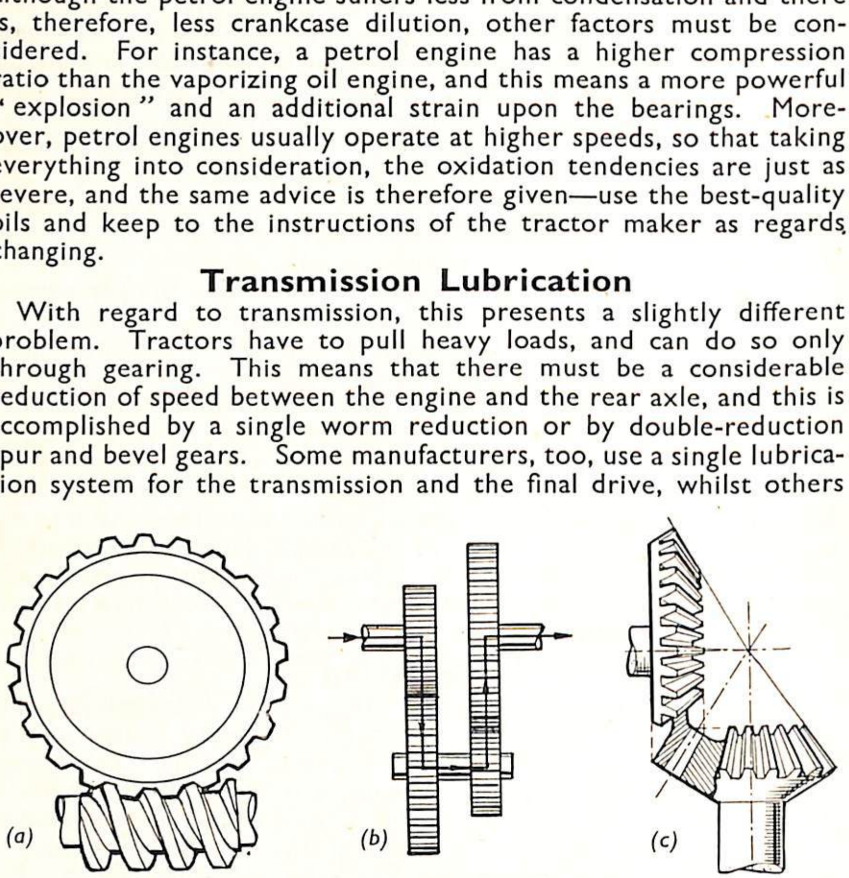


Fig. 43. TYPICAL TRANSMISSION SYSTEMS.
(a) Single worm reduction gear. (b) Double reduction spur gear. (c) Bevel gears. It is essential that a transmission lubricant be fortified so that it is not squeezed out from between these working surfaces.

There is, however, one feature common to all transmissions and final drives, and that is that they are all toothed gearing systems. When the teeth of two gears engage there is a certain amount of sliding contact between them, and their surfaces are under high pressure. The actual contact surface between them is only a line, so that the unit pressures are very high. It is accordingly essential that a transmission lubricant be fortified so that it is not squeezed out from between the working surfaces. It must build up in a film that prevents metal-to-metal contact, and thereby reduces friction, the rate of wear and the risk of breakdown. That is why some oils are manufactured with a film rupture strength of over 15,000 lb. per square inch.

The temperatures to which both transmission and final-drive lubricants are subjected are considerable. Some of the heat is generated by the friction on the gears themselves, and some is conducted through the casing from the engine, and although the temperatures do not reach those of engine oil, the lubricants do become loaded with metal particles and with dust, and should, therefore, be changed at the intervals recommended by the tractor makers.

Requirements of a Good Grease

With regard to greases, the requirements for front axles and steering are that they should be sufficiently soft to spread over the bearing surfaces, yet not be squeezed out by the jolting and jarring that is inseparable from tractor operation. They should, too, be water-repelling and protect the bearings against corrosion as well as wear. If greasing is done properly, and a good quality product used, it will form a dust-excluding seal.

Water pumps require a special grease, for it is in contact with water that is nearly boiling, so the grease must not melt at this temperature.

Thus lubricants are provided to assist in reducing the friction between rubbing surfaces, for, however smooth these may be, there is always a tendency to heat and a consequent reduction in the tractive effort received at the wheels. A bearing that is devoid of lubricant will, as has been said, become hot and will eventually "seize" solid.

It will be appreciated that there must be a space between bearings and the shafts which revolve in them, and when an engine is standing and is cold, the shaft sinks on to the lower half of the bearing and presses out a good deal of the oil from it. When running, however, the shaft rises a little so that it is actually not in contact with the bearing metal, but separated by a thin film of oil. Thus, when starting up an engine it is advisable to turn it round by hand just to spread the oil all over the bearing. In this manner much wear is saved and, as has been said, considerable strain on the starter battery. Bearings are, however, discussed in more detail in another chapter, to which reference should be made.

XII

BEARINGS

IT will be appreciated that should the oil become contaminated with particles of dust or grit, these will eventually find their way into the bearings and scratch and score them.

If you examine a number of bearings taken from engines, you will find that some of them have oil grooves cut across the bearing face, the idea being that these grooves will convey the lubricant all over the bearing. Many of the later type of bearings, however, are quite plain, the practice now being to let the chamfers do this work. The chamfered edges carry oil which is scraped off by the revolving shaft.

There is another type of bearing that will be encountered in machinery, and that is the ball. This consists of a number of hardened steel balls which run round a machined groove in a hard metal case. The balls are kept apart by a light metal cage. The complete ball bearing consists of an inner race, the balls, the cage and an outer race, and usually the inner race is a tight press fit on to the shaft, but the outer race is a "push" fit in its housing. The reason for this is that should the weight of the shaft and its load press at one point, it would eventually cause a failure in the outer case at that point. To prevent this the outer case is permitted to move slowly round in its housing so that every part of it bears its share of the load, thus adding to the life of the bearing.

When a shaft has to revolve it must be supported in bearings, and when rotation takes place, friction results. It is one of the purposes of the bearing to keep that friction to the minimum. The simplest bearing is a cylindrical hole formed in a piece of metal, the shaft being just a free fit. Such a bearing would offer considerable resistance if the metal and the shaft were of the same material, and so the hole is usually lined with a softer metal which not only offers less frictional resistance but may be replaced when wear occurs. The metal lining, or bush, also acts as a safety valve, for whenever two surfaces rub together, heat is generated, and unless it is conducted away the metals will become so hot that one or both will melt.

In addition to providing this safeguard, a bearing is designed to distribute lubricant to the rubbing surfaces, for if the design is sound there is actually no metal-to-metal contact when the shaft is revolving because a film of oil or grease separates the shaft from the bearing.

In some bearings only one part moves—an example being in shafting—and in others both parts move, such as the big-end bearings in a tractor engine. The part of the crankshaft which takes the thrust of the connecting-rod is called the journal, and the soft metal sleeve which is interposed between them is the actual bearing.

Bearings of this type are known as plain, and the bearing metal itself may be brass, bronze, white-metal, phosphor-bronze or an alloy, the one selected depending upon the load to be carried, the speed of rotation, and the contact area. Heavy, pounding loads are sometimes carried on phosphor-bronze bearings, one example being the big-end bearing in the Marshall tractor. In most tractor engines, however, a white-metal or an alloy bearing is used. On farm implements where there is but little speed, brass or bronze is used, and in the disc harrow it is the practice of some manufacturers to use hard wood.

It is obvious that upon the speed with which the parts move depends the type of lubricant to be employed. High-speed engine parts need oil, and slow-revolving parts are usually greased. If grease were used in high-speed bearings it would thin with the heat and run out, although the major objection is that grease would settle at the bottom of the sump and not reach the bearings at all.

Internal combustion engines are made so that either the oil is forced into the bearings by means of a pump (force-feed lubrication), or provision is made for scoops on the connecting-rod to dip into the oil and fling it all round the inside of the crankcase (splash feed), and little channels allow it to drain into the various bearings. Oil is also churned into a mist which keeps the cylinder walls oiled.

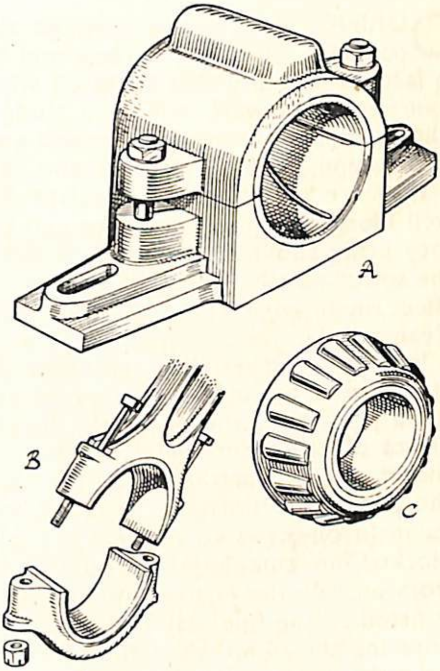


Fig. 44. Types of bearings. A. Bearing to carry shafting. B. Big end bearing to take engine crankshaft. C. Tapered roller wheel bearing.

Whereas a plain bearing is sliding friction, a ball bearing is rolling friction. In the former the bearing area is kept as large as possible to spread the load, but in a ball-bearing there is but a single narrow line of contact. This type of bearing is made in single and double rows of balls, and there are also some which have rollers instead of balls, these carrying greater loads. Some bearings have tapered rollers so that the load is not taken radially only, but has a side thrust in addition.

XIII

OIL AND AIR FILTERS

Oil Filters

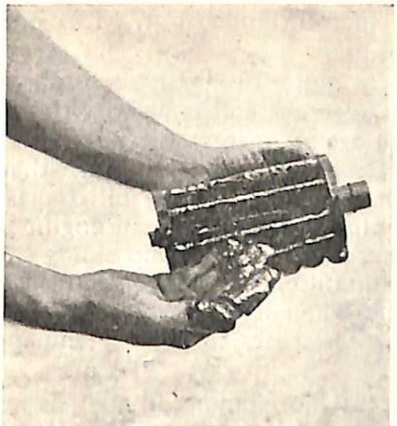
DURING its progress through the engine, oil picks up many particles of metal, carbon and other foreign matter. It has, in fact, been found that sump oil which has been in use for a short time contains swarf, sand and sludge (composed of metallic dust, silica dust, scale from oil pipes and a varnish-like matter that chokes oilways and gums up pistons), and all these substances are abrasive. If they are permitted to circulate through the system they might well block up the oil pipelines and so cause a seizure ; in any case they bring about increased wear to the bearings and the scoring of the softer metals. Dirty oil consequently has an accumulatively bad effect on an engine, and manufacturers take great pains to ensure a clean supply.

In some tractors there are four separate filters. One consists of a large sheet of gauze or perforated metal that is placed in the sump just above the oil level. Its purpose is to collect the larger pieces of carbon or metal. Then there is the filter—also gauze—that is placed over the end of the oil pipe leading from the sump to the pump. This strainer is of a finer mesh than the first one, and its main object is to prevent the oil pipes becoming clogged and blocked up completely. Often this second strainer is accessible from outside the engine. In addition to these, yet a third strainer is fitted to the filler-cap orifice to stop solid matter, fluff and so on entering the sump when the oil is poured in.

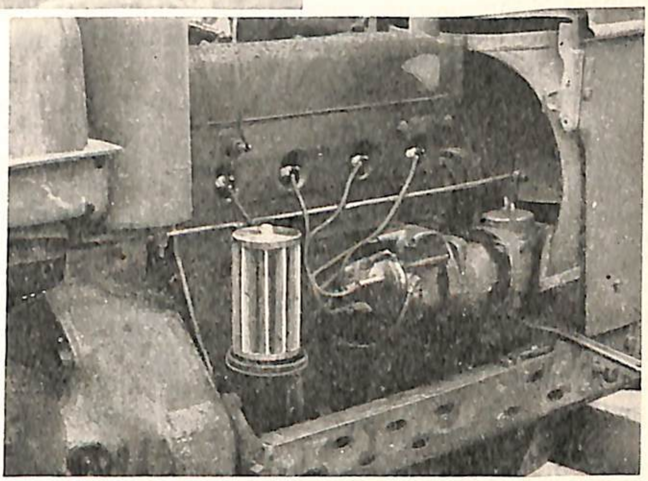
Lastly, there is the filter which is designed to remove practically all deleterious matter from the oil and to ensure that the lubricant re-circulated by the pump is as near as possible to a new oil.

Gauze filters are cleaned by washing them in paraffin, petrol or tractor fuel. They should be scrubbed lightly with a brush and *not* wiped with a rag, for this imparts fluff. There is a limit to the fineness of the matter which can be retained by a metal gauze filter, and many other types have been designed in an effort to prevent even the smallest of carbon particles from being re-circulated. It has been proved that one type of filter removes particles as small as .00004 in. in diameter, which is about a hundredth part of the thickness of a human hair.

The first requirement of any filtering installation is that all the oil should pass through it, but it will be appreciated that when the oil is very cold, considerable pressure would have to be used, and there is a possibility that this pressure would be capable of damaging the filter element. Without this pressure there is likely to be a period in which very little oil can get through the element, so that



(Left) The condition of this filter after a normal 120 hours' service, shows the necessity for regular replacement.



(Above) On tractors equipped with secondary filters, it is a simple matter, after removing the protecting cover, to replace the used pack or cartridge with a new filter.

(Right) Engines need protection from dust-laden atmosphere : oil in the bath must be kept at the proper level between changes.

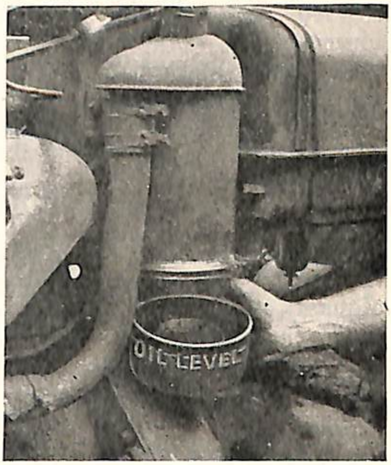


Fig. 45.

the bearings would be starved until the oil thinned out. To overcome this difficulty, a by-pass system is used.

The element itself is contained in a metal casing in such a way that oil passes into the inside of the element and is filtered on its way outwards. The element is held against a joint by means of a by-pass spring, but when the oil pressure rises to 2 lb. more than the normal, the element drops a little and allows the oil to pass through ports direct to the outlet pipe. Thus, when an engine is started up from cold, the full pressure of the oil pump sends the lubricant round the engine without the filter being involved. This ensures proper lubrication at a time when it is specially needed. As soon as the oil warms up, the by-pass ceases to operate and the oil then has to go through the filter.

Another feature of this filter is that the element is not resting on the bottom of the container, so that any accumulation of sludge is well clear of the element, and so does not impair its filtering qualities, nor is the sludge taken back into circulation.

It is clear that the larger the filter area the longer is its period of service, and so the element is constructed in a zig-zag form which, besides lengthening the life of the element, reduces the amount of pressure necessary to pass a given quantity of oil, which means that the speed with which the oil goes through the element is such that even the finest of the impurities are held back and are not forced through.

The actual cleaning medium consists of a special fabric that is clipped inside a perforated metal cage, and when necessary the material can be removed, opened out, and cleaned in petrol. After the accumulation of dirt has been washed off, the material is re-rolled and put back in its cage ready for insertion in the outer casing.

There are other types of filter in which the element cannot be cleaned, but is thrown away after it has done a certain amount of service.

Whatever method of filtering is employed, filters must receive proper and regular attention if they are to fulfil their purpose, and the instructions given by the tractor manufacturer should be strictly adhered to.

Air Filters

For every gallon of fuel that a tractor engine uses, something like 9,000 gallons of air have to pass through the carburetter. Such a quantity of air can hold a surprisingly large amount of dust, which, unless removed, gets into the cylinders and causes considerable wear, and also contaminates the oil.

Several types of air filter are used on tractors, and so important is clean air that some manufacturers fit two separate cleaners. On the Fordson Major, for instance, there is on the top of the air-intake pipe an ingenious device for extracting the larger particles of dust and foreign matter. This primary cleaner comprises a number of small vanes through which the ingoing air has to pass, and in doing so it is given a rapid swirling motion which flings chaff and dirt upwards and outwards, striking the underside of the cleaner cover and passing out into the atmosphere through four other vanes.

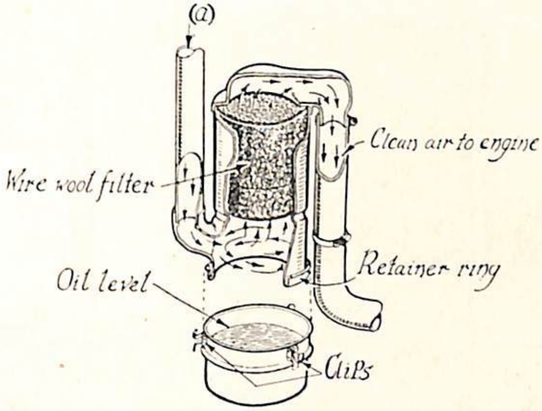


Fig. 46. Combination air cleaner showing flow of air over the oil in the reservoir and through a wire wool filter.

The two main types of air cleaner are those in which some form of metal wool is used, and those in which the air is made to impinge onto oil. Frequently a combination of the two is built into a single filter unit, of which an example is given in Fig. 46.

In this filter the air enters by the passage (a) and passes over the surface of the oil in the reservoir. Dust and other matter stick to the oil and gradually sink to the bottom of the well, the air going upwards through fine wire wool, which still further cleans it.

Fig. 47 shows the air filter on the Marshall tractor. This uses coconut fibre instead of steel wool. The material is enclosed between two cages so that all the air has to pass through the fibre before it can reach the engine. This filter is serviced by taking the fibre out of the container, washing it in paraffin and then spreading it out to dry. A pint of thin engine-oil is then warmed slightly and the loosened fibre dipped into it and squeezed by hand until the fibre is all moistened but not saturated. It is then carefully pressed back into the cage with a piece of wood. Packing should not be tight, but no space should be left through which air can pass unfiltered.

Oil-bath filters are cleaned by simply removing the well and tipping out the dirty oil. After thoroughly cleaning both the well and the top part of the canister, fresh oil is poured in to the correct level. Some operators are under the impression that as this oil has not been through an engine it can be used to lubricate implements and other machinery, but to do this is as bad as dropping a handful of emery powder into clean oil and using that. Old filter oil should *never* be used again unless it has first been put through a special oil-reclaiming plant.

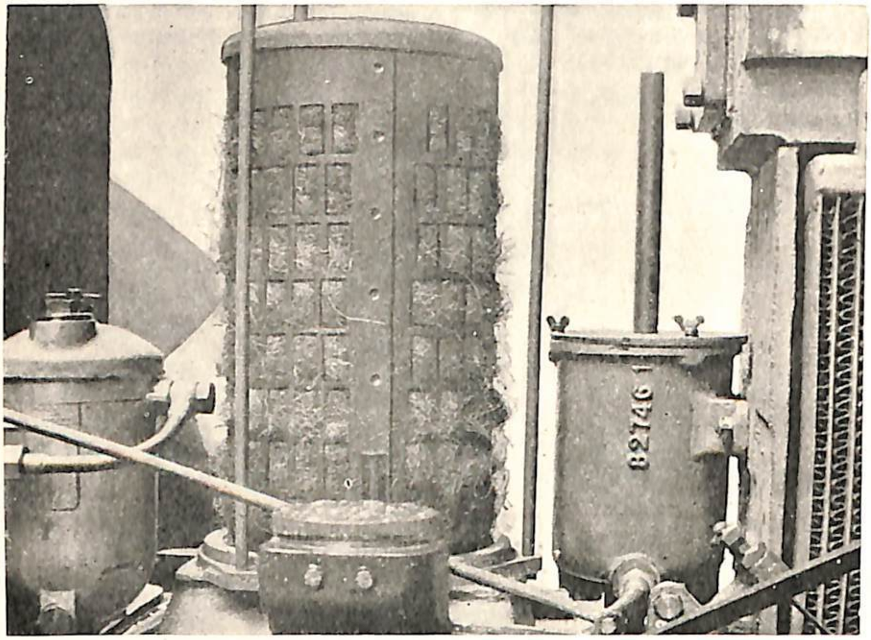


Fig. 47. Air filter packed with coconut fibre on Field Marshall tractor.

XIV

COOLING

THE internal combustion engine is known as a " heat " engine, for it converts the potential heat energy contained in the fuel into work. In doing this it by no means uses all the heat liberated, for actually only about 25 per cent. of the total heat generated is converted into work, and some 40 per cent. is wasted in the exhaust gases. The balance is imparted to the pistons and cylinder walls. It is essential that this be removed as quickly as possible, because none of the metals used in engine construction can endure for very long the temperature of combustion.

In some of the smaller industrial-type engines this heat is dissipated by means of an engine-driven fan, but the system is not practical if there are more than one or two cylinders, partly owing to the large-sized fan that would be needed, and partly because a complicated system of ducts would be necessary. The most common means is to use water which is made to circulate round the cylinder heads and through a radiator. The radiator is a system of tubes—usually carrying fins—placed in the front of the machine so that it gets the full benefit of the air. In many cars a large radiator is all that is necessary, because the speed with which the vehicle is driven through the air is enough to keep the temperature of the water down to under boiling-point. Nevertheless, it is customary to fit a small fan which assists in keeping down the temperature when the vehicle is moving slowly through traffic or is climbing hills on low gears. Because of the slow land-speed of tractors, and the amount of work they have to do when driving machinery off the belt pulley, a large-size fan is used, plus a pump which speeds up the water circulation. Without the pump the water would quickly boil away and the engine overheat.

Engine Water-pumps

Water pumps are simple things, for they consist of a vaned member rotating in a casing. Such pumps are called centrifugal pumps, because the spinning vane throws the water into a pipe thus ensuring a circulatory motion throughout the engine and radiator. The most important part of a tractor water-pump is the gland, or water seal, and this may take the form of a spring-loaded packing impregnated with graphite, or it may be simply a length of graphited string held in place by a gland nut. Naturally, the object of the gland is to prevent water leaking between the rotating shaft of the impeller and the stationary casing, but in addition to this the gland frequently provides lubricant to the shaft. Thus if the gland packing is tightened up too much, it not only prevents the slight seepage of water (which is the lubricant for the shaft), but it may press so tightly on the shaft that it imposes a severe strain on it. A gland should be tightened only sufficiently to prevent leakage, but should allow a seepage. When a new packing has been inserted it should be tightened down lightly at first, and then gradually tightened a little more as it beds in.

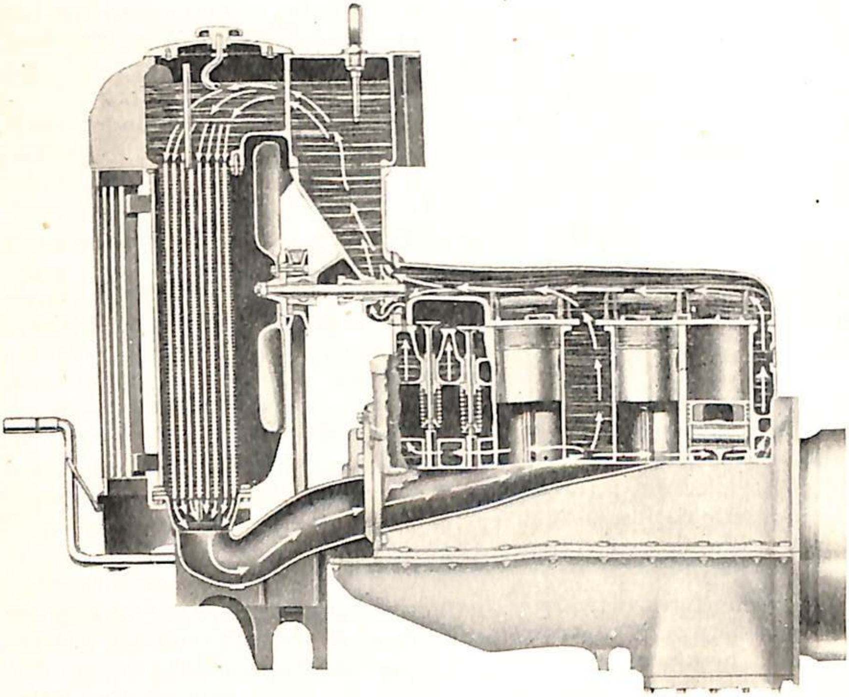


Fig. 48. Diagram showing the direction of water flow in cooling system of Fordson Major tractor.

Thermostat Control

Some cooling systems incorporate a thermostat control which eliminates the necessity for the operator to close the radiator blind in cold weather. Thermostats are made in two types, one consisting of a series of thin metal rings connected together to form a bellows, and the other comprising a spring made of two metals, brass and invar, which expand at unequal rates. The bellows thermostat is filled with liquid which expands and contracts according to the temperature of the water surrounding it, so that by means of levers, a radiator shutter opens and shuts. The bi-metal device operates similar levers. There are some systems which by-pass the water so that when the engine is cold only that water contained in the cylinder block is permitted to circulate until the temperature approaches the normal operating temperature of the engine. At this point the radiator water is connected in the " line."

Tractor engines should be made to work at a temperature of 160° F. to 180° F., for at lower temperatures the fuel consumption is higher, and above 180° there is a risk of the water boiling away when the engine is at full throttle. At high temperatures, too, many engines are liable to " pink," although this is more likely to occur with a petrol-driven engine than one running on vaporizing oil.

It is worth mentioning here that a boiling radiator is not necessarily a sign that the water is not circulating properly, for it may be that the fuel mixture is over rich or even too weak. Other causes of heating-up are a retarded ignition, low level of engine oil in the sump, and unsuitable oil. Dragging brakes and overloading are other causes. Then the tightness of the fan belt should not be overlooked, nor should the water level in the radiator. Whatever the case, it should be found at once and remedied. If steam is issuing from the radiator filler cap, do not unscrew it until the engine has cooled down or a severe scald may be the result. If the water level is low, let the engine cool before adding more, otherwise there is every chance of cracking the cylinder block.

Fan Belt Adjustment

Fan-belt adjustment is usually a simple matter, for almost without exception it is achieved by widening or narrowing the fan-belt pulley behind the fan. These pulleys are made with two separate flanges, which screw on to a shaft. Screwing in the outer flange narrows the pulley and tightens the belt. On those tractors fitted with dynamos it is usually possible to adjust the belt tension by swinging the dynamo on its mounting, for the dynamo pulley acts in the same manner as a jockey pulley.

Causes of Overheating

If overheating occurs when the crankcase oil level is correct, the right oil is used, the water level in the radiator is right and the fan belt adjusted properly, then the trouble is most likely due to some obstruction in the circulation system. A simple test is to grip the water hosepipe leading to the top of the radiator, and then to open up the engine throttle quickly. If the circulation is free there will be a distinct increase of pressure in the hose as the engine speeds up. This test cannot, of course, be applied if the tractor has a thermo-siphon system, for there is no change of pressure.

A common cause of overheating is the furring-up of the radiator, due to the use of hard water, or to the accumulation of muck in the water (i.e., dead leaves, straw and so on). To flush out a radiator it is best to make the water flow through the opposite direction to that of the normal so as to loosen the deposit. If the stoppage is due to fur, use one of the preparations—such as " Epheta" —to clear it.

Overheating may also be caused by an accumulation of dust and dirt in the radiator grill, particularly after the tractor has been used for threshing. This grill should be periodically cleaned out by compressed air or water pressure directed through the grill from the engine side of the radiator—i.e., the flow should be opposite to the sucking action of the fan.

Much trouble is caused by the use of wrong anti-freeze solutions. Many people, in an endeavour to obtain something cheap, have used commercial glycerine in the water, but this may attack the rubber hose, and may even corrode the engine cylinder-jacket. Solutions of calcium chloride should not be used, as they have a harmful effect upon the engine and particularly upon aluminium parts. It is unwise, too, to keep an anti-freeze solution in the radiator throughout the summer.

XV

MAGNETOS

A MAGNETO utilizes two fundamental laws of electrical behaviour : (1) If a piece of wire forming a circuit is made to pass through a field of magnetism, an electric current is set up in the wire ; and (2) if a current of electricity is passed through a wire, a magnetic field is set up around the wire. Most people are familiar with the ordinary horseshoe magnet that will pick up small pieces of iron and steel. An invisible magnetic field flows between the ends, or poles, of the magnet, and this field attracts iron. In a magneto we have a horseshoe magnet with the ends set wide apart, and between these ends is a piece of soft iron which can be made to revolve.

Primary Winding

Around this soft iron " core " is wound a length of insulated wire, and when the two ends of the wire are joined together and the core and coil revolved, the magnetism from the permanent magnet surges through the core and flows around the coil, producing a current of electricity. This current is a weak one, and although it would light a torch lamp, it would not jump across the points of a spark plug.

According to the second law, current sent through a wire sets up magnetism around the wire, so the purpose of the coil mentioned is to magnify or produce more magnetism. Now it has been found that when the ends of the coil are joined suddenly the magnetism builds up around the coil suddenly, and when the ends of the coil are separated, the magnetism collapses quickly. The coil we have been discussing consists of a few turns of wire, and is known as the primary winding, and the device which joins the two ends and which breaks them apart again is called the contact-breaker ; it is merely a mechanical switch.

Secondary Coil

So far, then, we have a machine which will make a strong field of magnetism. In order to get a current of electricity strong enough to jump across the points of the sparking plug when it is surrounded by compressed air and fuel vapour, it is necessary to have plenty of pressure behind it. We get this by applying law No. 2 again, for over the primary winding is wound a second coil of insulated wire. This wire is much thinner (being about the thickness of a hair), and there may be as much as a mile of it.

The magnetism which is produced by the primary coil cuts across the secondary coil, and this produces a " high-tension," or high-pressure, current in the secondary wire. The magneto is fastened to the engine and geared so that at exactly the right time the magnetism from the permanent magnet which is surrounding the primary coil is collapsed by the opening of the contact-breaker points. The collapsing field of magnetism passes very rapidly across the secondary winding and produces a current of electricity at the sparking-plug points.

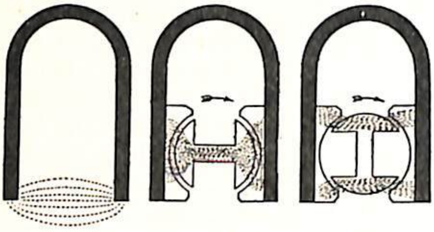

(a) (b) (c)

Fig. 49. Horseshoe-type permanent magnet showing control of magnetic flow through rotating core.

Let us now illustrate this with a few simple drawings. Fig. 49 (a) shows a horseshoe-type permanent magnet with the magnetism indicated by little dashes. In Fig. 49 (b) we have the soft iron core in the position in which the greatest amount of magnetism flows through the main part of the core; and in (c) we see the core in such a position that the magnetism takes the easier path through the curved ends of the core, leaving none to pass through the core body.

Fig. 50 is a much simplified diagram of the essentials of a high tension magneto. In actual practice, as we have said, the secondary winding is wound on top of the primary, but here it is shown so that all the connections are easily seen. It will be noticed that there

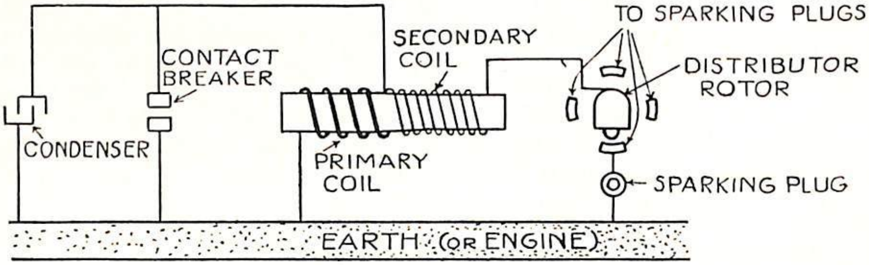


Fig. 50. Simplified diagram showing essentials of high-tension magnets.

are two complete circuits. The primary circuit is from " earth " (or the engine casting), up through the primary winding, across the contact points and back to earth. The secondary circuit is from earth, through the secondary coil, then through the distributor and across the sparking-plug points and back to earth. It might be mentioned here that the distributor is simply a revolving switch which permits the high-tension current to pass from the secondary coil to each of the sparking plugs in turn.

The Contact-breaker

The efficiency of the machine largely depends upon the condition of the contact-breaker, for this has to make and break contact every time a plug fires. Thus, if the tractor engine is running at 1,000 r.p.m., the four plugs fire a total of 2,000 times, which means that the contact-breaker opens and shuts 33 times a second ! To ensure a good spark, the contact points must be kept clean and the rocker-arm working freely.

As far as the tractor operator is concerned, the contact-breaker is the most important part of a magneto, for, as we have already seen, it has to function many times a second. Every part must, therefore, be kept in good order if trouble is to be avoided. Fig. 51 shows a simple contact-breaker, and although that on your own tractor may be different, they all contain the essentials given in our picture.

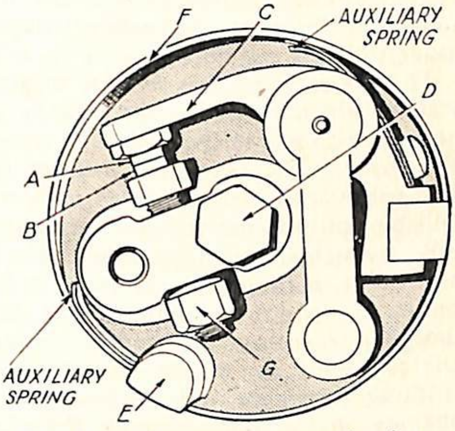


Fig. 51. Diagram of contact-breaker. Explanation of lettering is contained in the text matter.

The two contact points are shown at A and B, the former being fixed and the latter adjustable. Contact point A is fastened to the rocker arm, which is pivoted and carries a fibre pad which slides over the operating cam and opens the points. Contact is again made by the operation of the main spring F. In most magnetos and in some coil-ignition contact-breakers, two small auxiliary springs are fitted, one at each end of the main spring. Their purpose is to distribute the tension evenly over the whole of the main spring and not allow any part of it to receive the full force of the flexing movement.

In some magnetos there will be a condenser on the contact-breaker unit, but in others it is placed in the armature and revolves with it.

Servicing the Lucas 4V RA Magneto

The Lucas 4V RA is an interesting example of magneto construction, for it is designed to be mounted vertically or at a slight angle in the same way as a distributor, so that engines designed for use with coil ignition can be changed over to magneto without difficulty. The machine is of the rotating-magnet type, which means that the less robust parts are stationary. The drive is at half engine speed, and no gearing is needed between the rotor shaft and the contact-breaker. The magnet and pole system is arranged so that the number of sparks produced for each revolution of the magneto rotor is equal to the number of engine cylinders. Thus, for a four-cylindered engine the 4V R is used, and for a six the 6V R.

The magneto is fitted with an automatic advance and retard mechanism of a type common on most coil-ignition systems. The high-tension current is carried from the secondary coil through a flexible rubber-insulated cable to the distributor, which itself forms a cover to the contact-breaker. Impulse starters are fitted to other models of this magneto.

To service the Lucas 4V RA magneto, unfasten the two knurled screws which hold the distributor in place and pull off. If it is necessary to get at the coil unit, remove the two screws and detach the cover. The magneto, without its covers, is shown in Fig. 52. The rotor arm, marked " A," pulls off in the usual manner ; but it will be noticed that it has an attachment consisting of a brass plate " B " (which slides in grooves and is held to the centre by springs) and a flat, curved strip of metal " C," which has a projecting lug on it. In addition to being the safety-spark gap, this device is designed to cut out the ignition should the engine speed rise beyond the safe limit, for as the magneto spindle revolves, the plate " B " is flung outwards and eventually contacts the lug. The tension springs on the plate should, therefore, never be interfered with in any way.

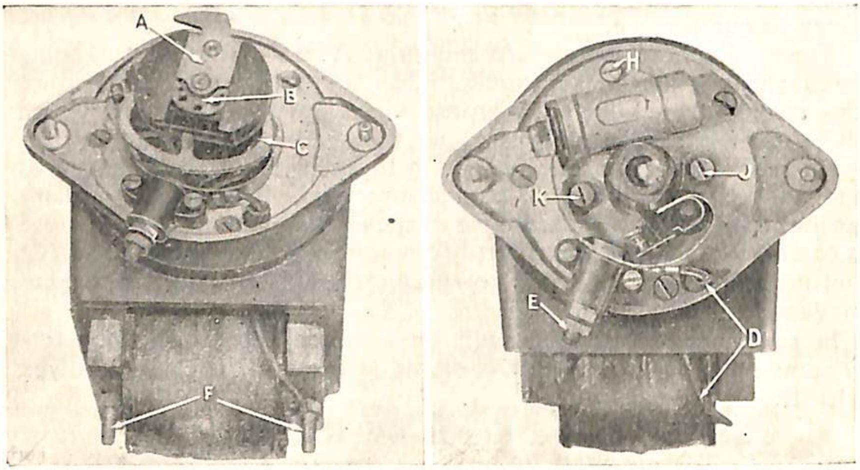


Fig. 52. *Fig. 53.*

The Lucas 4V RA magneto.

In Fig. 53 we have a slightly different view, and the distributor rotor has been removed to show the contact-breaker. The insulated wire " D " passes from the primary coil, through the magneto body and is secured to the earthing switch terminal " E." To remove the coil unit, take out the two setscrews marked " F " in Fig. 52. These screws are constructed with a thread at each end and a nut in the middle, the top thread taking the coil-cover screws. The switch terminal has two nuts on it. Slacken both of these back a turn or two and press down the terminal, thus allowing the spade terminal on wire " D " to be withdrawn. The wire is then pulled through the hole in the magneto body as the coil unit is lifted away. Remember that whenever the armature of the coil is taken from the machine, a " keeper " of iron or steel should be put across the pole pieces to preserve the strength of the magnets.

To remove the condenser, slacken the screw marked " H " in Fig. 53, and if the two nuts on the switch terminal have not already been disturbed, do this next, when the condenser and the curved metal strip can be lifted out. The contact-breaker is simple to service, the design being such that no auxiliary spring is needed for the rocker-arm spring, and that the L.T. wire, contact-breaker spring and condenser are all connected to the one terminal.

Should the contact points become pitted, it is best to remove them completely and re-face each separately, unless one has a special diamond-dust-impregnated strip.

The fibre rocker arm is pivoted on a bronze pin. To take out the rocker, slacken the earth switch pin nuts and gently lift the rocker off its pivot, easing the spring away at the other end. The fixed contact is removed by taking out the two screws marked " J " and " K " (Fig. 53), when the plate carrying the contact may be lifted out. Place the contacts in a vice and trim them with a magneto file or a piece of fine emery cloth backed with a strip of wood. Keep the surface of the contact as flat as possible, and remove all pitting, leaving the surface clean and bright. Smear the rocker-arm pivot with a very small amount of Mobil-grease No. 2 every 250 hrs. of running, and after every 150 running hours give the cam a smear of the same grade of grease. Replace the contacts and then adjust the cap. To do this, first rotate the spindle until the points are fully open, then move the fixed contact plate until the gauge just slides comfortably between them, then tighten both screws firmly.

Occasionally remove the distributor and clean the electrodes with a cloth moistened with petrol, and wipe the inside of the cover with a clean duster. See that the carbon brush is clean and moves freely in its holder. Clean the outside of the moulding, particularly the spaces between the terminals.

The magneto is usually carried in a clip attached to the timing lever. The timing can be adjusted by loosening the clamping screw on the clip and turning the magneto in the desired direction. If the magneto has to be removed from the engine it is advisable to mark the position of the magneto body, lever and rotating arm, so that the machine can be replaced in the same position, and so avoid re-timing.

Resetting Timing of Magneto

Should the timing be upset for any reason, endeavour to keep to the engine manufacturer's instructions, but if these are not known, proceed as follows : Turn the engine over until No. 1 piston is at top dead centre of the compression stroke. Next, half retard the hand ignition control, if this is fitted. Then turn the magneto so that the contacts are just about to open when the metal electrode on the distributor arm is pointing to the insert in the moulding connected to No. 1 sparking plug. If necessary, slacken the clamping screw on the timing lever and turn the magneto until this position is found. After setting and checking, tighten the clip.

To lubricate the automatic timing control and the magneto shaft, fill up to the level of the lubricator with thin machine oil once a month. Remember to keep the sparking-plug gaps to .020 in. and to replace any high-tension cable which shows signs of perishing or cracking. Use only 7 mm. rubber-covered ignition cable for all high-tension leads. The fixing screw for the centre terminal of the distributor cover is accessible when the carbon brush is withdrawn.

Coil Ignition

Some tractors are fitted with coil ignition, the Ferguson being but one example. Fundamentally there is not a great deal of difference between the two systems. The coil system comprises an accumulator for supplying the primary current, a coil, and a combined contact breaker and distributor, thus giving us three separate units instead of one. It should be noted, however, that in magneto ignition, switching off is accomplished by earthing the primary current so as to prevent it from passing through the winding, whereas in coil ignition, switching off actually prevents the primary current from flowing at all. Apart from this difference, the servicing and maintenance details given apply to either type of contact breaker and distributor.

Tracing Ignition Faults

The best way to trace ignition faults is to tackle the job systematically so that each test either finds the fault or eliminates certain parts of the system as being satisfactory. It must not be forgotten that ignition trouble is not the only thing that will prevent an engine from starting, so before inspecting the magneto see that the fuel supply is in good order.

Begin your ignition tests by checking the ignition switch and cable. Disconnect the switch cable from the magneto contact-breaker and try to start the engine. If it fires, then the fault is in either the cable or the switch. Unlike coil ignition, earthing the primary winding switches off a magneto, so by disconnecting both cable and switch they are tested together. To test the cable itself (assuming that the engine starts when it is disconnected) replace the connection at the contact-breaker but disconnect it from the switch. If the engine starts, then the fault lies in the switch.

If the above test fails to produce a start, the next thing is to see if any spark at all reaches the plugs. There are three simple checks for this, the first being to remove the plugs from the cylinders and to lay them on the engine. The high-tension cables should not be removed. Turn the engine over with the starting-handle and note if a spark is obtained at each plug in turn. The second method is to put a screwdriver point on the cylinder head and to hold the blade a sixteenth of an inch or so from the plug terminal. If the current passes a spark will jump across the gap. But make sure that the screwdriver has an insulated handle or you will get a shock.

The third method is to use one of those small neon-tube plug testers. In this case it is necessary only to touch each plug terminal in turn, when a flash will be observed in the tube if a spark occurs at the plug. No spark on any of these tests may mean : (a) a plug is sooty and the gap between the points bridged by carbon ; (b) too large a gap or no gap at all ; (c) the insulator is wet, thus allowing the current to pass directly to earth ; and (d) the high-tension cable is broken or disconnected, or the insulation is perished and allowing a " short." Check over all these things before proceeding with further tests.

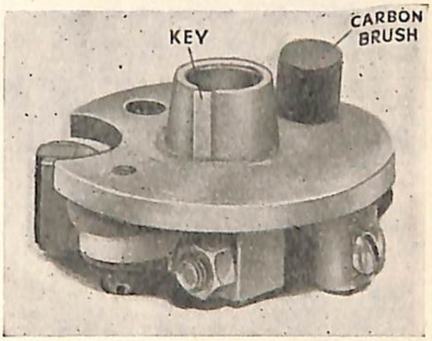


Fig. 54. Back view of contact breaker removed from Lucas GJ4 magneto.

The next thing is the contact-breaker, the care and maintenance of which has already been dealt with. The usual rapid check is, on the Lucas GJ4 and similar types, to slip off the cover and to operate the rocker arm with the finger to see if it returns freely. Next, unscrew the breaker and remove it, and examine the small carbon brush in the back. This brush is shown in Fig. 54. This illustration also shows the pressed key in the centre boss of the contact-breaker base. Make sure, when replacing the breaker, that this key fits into the groove provided for it in the magneto. Unless the breaker is positioned correctly the key will become damaged and the points will not open at the correct time. The carbon brush conveys the primary current from the coil to the contact-breaker, and if it sticks in its hole, there will, of course, be no spark at the plug. Should the engine again fail to start after the contact-breaker has been checked and carefully replaced, examine the distributor. There may be moisture inside the moulding, and this will provide an earth path for the current. If tracking is due to dirt, it will, if allowed to continue, ruin the moulding of the distributor. After wiping the distributor dry, examine the segments to see if they are dirty or pitted. Pitted segments should be rubbed over very lightly with a smooth file, but do not remove any metal, as this will increase the gap over which the current has to jump and make starting more difficult.

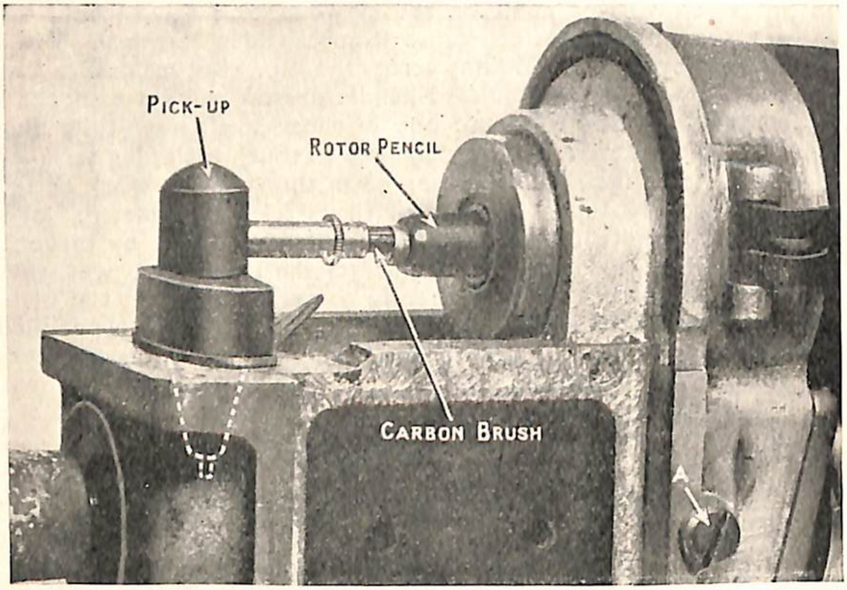


Fig. 55. Pick-up in position on magneto.

The Pick-up

Next take out the pick-up. This is usually a small moulding containing two carbon brushes, one of which presses on the slip-ring of the armature, and the other on to the " pencil " which carries the distributor rotor. Fig. 55 shows the pick-up in position ; the magnets have been removed to ensure a clear view. Fig. 56 shows the pick-up itself. Note the two carbon brushes, which should work freely in their guides, yet have sufficient spring to make good contact. There is another

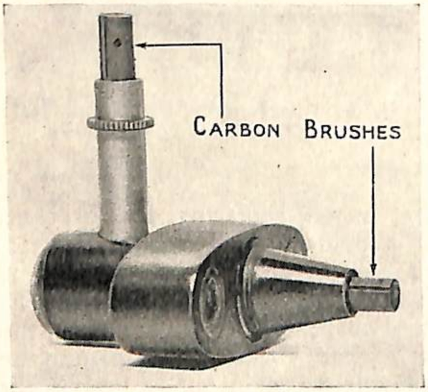


Fig. 56. Pick-up removed from magneto, showing carbon brushes..

carbon brush to inspect, and this is usually found underneath the magneto. It presses on to the armature drum, and its function is to earth the primary coil. In the magneto shown in Fig. 55 this brush is fitted in the side and is shown marked at A.

The Sparking Plug

An essential part of the electrical system is the sparking plug. Tractor performance can be much affected by the type and condition of the plug used, and care both in selection and maintenance is well worth the trouble. In order to function properly, a sparking plug should have sound insulation, be gastight, operate for long periods without failure, be resistant to rust, and not pre-ignite the fuel.

The exploded drawing, Fig. 57, is of a Wico plug. It has a rust-resisting body (A) of zinc-coated steel, which screws into the cylinder head. A pure nickel point (B) is fastened to the body and provides the earth return for the current. The central electrode (C)—also pure nickel—has to be completely insulated from the body.

In plugs designed to be dismantled for cleaning purposes, the central electrode and its insulation are held in the plug body in such a way that the joint is completely gastight, and this is achieved by a copper joint ring (D) that is tightened down on to the body by a steel gland nut (E). The upper end of the electrode has, of course, provision for the attachment of the high-tension cable.

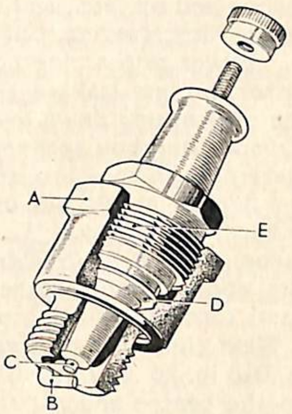


Fig. 57. Sectional view of "Wico" sparking plug.

Combustion temperatures are very high, and unless the heat is quickly conveyed away from the central electrode, the point will become so hot as to be incandescent, resulting in rapid burning of the metal and the pre-ignition of the fuel. Engines do not run at the same temperature, however, and a plug suitable for one is not necessarily correct for another. For this reason plug manufacturers make various types, some for "hot" engines and others for "cold" engines, with possibly a dozen types in between these extremes.

Heat control is secured in several ways, and one common method is by altering the length of that portion of the insulator surrounding the central electrode. A long uncovered electrode, therefore, indicates a hot point and one suitable for a "cold" engine. Other plugs rely upon a copper sleeve interposed between the electrode and the insulation, and yet a third method of control is to vary the size of the cavity between the electrode and the plug body. In the main an electrode should run hot enough to burn off carbon, the presence of which is an indication that the plug used is too "cold."

A further consideration is the length of the plug body thread, and some engines are so designed that the normal thread length of a plug does not permit the points to go far enough into the combustion chamber, thus forming a pocket from which the hot gases are seldom scavenged. Thus, from what has been said about suitability, readers are urged to make quite certain that replacement plugs are really suitable for their make of engine. The best way is to look up the tractor maker's handbook and order the plug he recommends.

We come now to the question of maintenance. To most people this is simply a matter of taking the plug to pieces, scraping away carbon and oil, etc., and setting the gap after re-assembly. Up to a point this is correct, but there is a right and a wrong way of doing it. Never grip a plug body tightly in a vice, for this may result in distortion, gas leakage and fracture. The safest method is to turn the plug upside down and lightly grip the gland nut in a vice, using a well-fitting box spanner to unscrew the body. Wipe the central electrode and its insulation in a petrol- or paraffin-soaked rag if the deposit is soft, but use a piece of fine emery cloth if the deposit is hard. Scrape out the inside of the plug body and wash away all carbon and abrasive material before re-assembling, taking care that the copper joint washer is clean and undamaged. Replace the parts carefully and tighten the gland nut.

Next check the plug gap with a feeler gauge. The normal setting is .018 in. to .020 in. If the gap is too big, bend the side electrode to the centre and *not* the centre electrode to the side, for by so doing you may fracture the insulation. The feeler gauge should just slide comfortably between the points and neither force them open nor wobble about.

Although most sparking plugs will give many months of service, particularly if looked after properly, they do gradually deteriorate. This deterioration is so slow that it usually passes unnoticed. It is, therefore, a good plan to have a new set of plugs handy and to try them occasionally. If a noticeable improvement is felt, then keep the new ones in and scrap the old set.

The Impulse Coupling

When a large engine fitted with magneto ignition is started by hand the speed of rotation is so low that the magneto will often fail to produce a spark of sufficient intensity to ignite the mixture in the cylinders. For this reason a device called an impulse starter, or impulse coupling, is fitted. This mechanism temporarily prevents the magneto armature from revolving, but when the piston—usually that in No. 1 cylinder—is at the top of its firing stroke, the armature is flicked rapidly through the magnetic field and produces a hot spark.

As difficulty is sometimes experienced in understanding how this is achieved, a simple piece of apparatus will show what happens.

Suppose we have an arrangement as that in Fig. 58, consisting of a piece of string (A) with a small weight on one end (D). At some point along the string we have a pair of contacts (B), which are normally kept together by a flat spring. When the other end of the string (C) is pulled in the direction of the arrow, D will travel towards B at the same speed that the string is pulled, and eventually it will reach the spring and open the contacts.

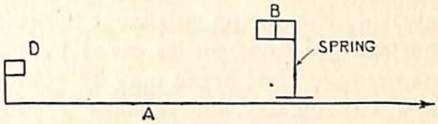


Fig. 58. Explanatory arrangement of action of impulse coupling.

If, however, the string is replaced by a piece of elastic, and this is held at the point D, pulling the end (C) merely stretches the elastic. Then if D is released when the elastic is fully stretched, it will travel along and reach the spring at a high speed.

This is, in effect, what happens in an impulse starter, for the movement of A represents the rotating of the engine, B the firing point on No. 1 cylinder, and D the cam which operates the contact-breaker arm. We accordingly see that although the engine is turned, the armature shaft of the magneto—and, of course, the breaker—does not revolve. But immediately D is released the breaker turns rapidly and opens the points at the correct time.

In one simple form of coupling a plate which is keyed to the armature shaft carries on it a small pivoted lever. As the engine starts to turn, the plate and lever turn also, but further movement is prevented by the lever's coming into contact with a projection on the magneto body. The engine still revolves, and this action winds up a powerful spring which is contained in a metal drum driven by the engine camshaft. When the spring is fully wound the lever which prevents the armature from revolving is released, the spring unwinds, and the armature is flicked round rapidly.

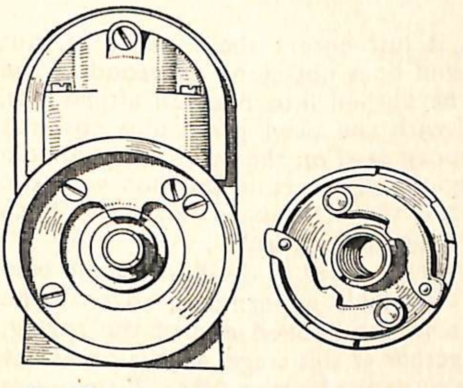


Fig. 59. View of magneto with impulse coupling removed.

Impulse couplings will operate for a long time without attention, but sometimes they become clogged with dirt and the spring may break. To dismantle the coupling on a Fordson tractor, first remove the magneto and then unscrew the nut in the centre of the impulse coupling which holds the assembly onto the armature. This nut is secured in the coupling by a spring retaining ring, so when the nut is unscrewed it acts as a puller and draws the coupling from the shaft. The magneto is shown in Fig. 59.

Remove the outer snap ring which secures the inner member to the outer case. Withdraw the inner member, at the same time releasing the spring so that it is retained in the outer case. Each of the pawls is kept on its pivot by a small washer fastened by a tiny snap ring. The spring may be removed from the outer case, taking care to release the tension gradually. It may be necessary to remove the coupling securing nut—the one that was unscrewed first—and if a well-fitting box spanner is not used, the edges will be turned off. The nut is held in place by another snap ring. Fig. 60 shows the spring in its housing.

Before reassembling, grease the torsion spring and the fibre strip interleaved with it, and engage the inner ends in the slot machined on the boss of the inner member, so that the spring is wound in a clockwise direction. The fibre strip should not extend into the hooked outer end of the spring, otherwise difficulty may subsequently be experienced in engaging the lug of the inner member.

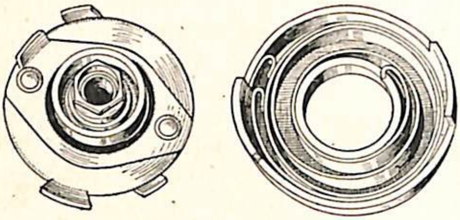


Fig. 60. Securing nut on impulse coupling in position and (right) the spring in its housing.

Wind the spring up so that it just enters the outer case, but ensure that the outer hooked end does not stand so proud of the remaining coils that it cannot be pushed into position afterwards. Next hold the inner member with the pawl pivot pins towards you and horizontal, place the upper pawl on the left-hand pivot pin with the trailing part to the right, and secure in position with the flat washer and the circlip. Install the other pawl similarly. Both pawls should rotate freely within the limits of travel.

Place the large boss of the inner member in the bore of the case which holds the spring (i.e., the pawls uppermost), so that the protruding lug may be inserted in the hooked end of the spring. Do not press the two halves together at this stage, as it is necessary that the spring be given about a quarter of a turn first. If the lug is first hooked in the spring and then gently withdrawn, it will lift out the spring end enough to permit the inner member, which carries the pawls, to be turned to the right, until the lugs which point upwards are moved over those lugs on the other member. When this has been done, press the two members together and secure with the circlip. This circlip will, of course, be the one first removed. If the nut itself has been taken out, it will have to be inserted and locked with its circlip before the two members can be fastened together.

Timing the Magneto

To time the magneto, rotate the crankshaft with the starting handle until No. 1 cylinder is at its firing point. This is when the piston is at top dead centre with both valves closed. The easiest way to find this position is to remove the valve cover and also the sparking plug from No. 1 cylinder and insert a piece of wire down into the plug hole so that it touches the top of the piston. Rotate the crankshaft until both valves are closed (this will be when neither spring is compressed) and the upward movement of the wire stops.

Remove the distributor cover from the magneto and rotate the impulse coupling anti-clockwise until the rotor arm is pointing towards that segment of the distributor numbered 1, and to which the high-tension lead from No. 1 plug should be connected. Turn the armature so that the points are just about to open with the rotor arm in the position described. The lugs on the coupling will be approximately horizontal and the lugs on the driving shaft vertical. Install the fibre coupling and slide the magneto forward on its bracket, insert the four magneto securing screws and tighten them. Replace the distributor cover and re-connect the high-tension lead and, of course, the valve cover.

XVI

DYNAMOS

THE general principle upon which a dynamo works was described in Chapter XV, for a magneto is actually a dynamo in this case producing alternating current. At this point, therefore, we can turn directly to a consideration of the type of dynamo used on tractors.

As a rule the casing is of cylindrical shape and contains the field magnets. These have pole shoes shaped to embrace the armature, which is mounted centrally within the casing, and is carried in bearings at each end. One of the covers in which the bearings are fitted also carries the brushholders, and these, in turn, are provided with carbon brushes that bear on the commutator fixed on the armature shaft, as shown in Fig. 61.

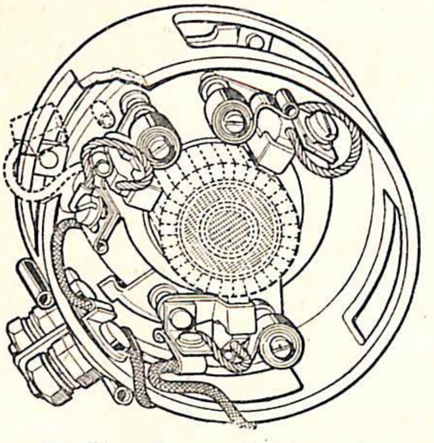


Fig. 61. Dynamo showing carbon brushes bearing on the commutator.

The armature itself consists of a large number of soft-iron stampings assembled in a compact mass, and afterwards machined to an exact diameter. Each stamping is slotted in such a manner that, when assembled on the shaft, the slots form longitudinal grooves, and in these are wound coils of insulated wire connected at their ends to the bars of the commutator. It is important, of course, that the windings shall be fixed rigidly in place to resist the effect of centrifugal force when the armature is rotating at a high speed ; furthermore, the armature must be balanced so that it runs without vibration, as the clearance between it and the surrounding pole pieces is very small—only a few thousandths of an inch. This clearance is known as the air gap.

There is usually one field magnet (with a total of two poles or faces) in the modern tractor dynamo, but at one time the four-pole dynamo was common, and some machines of this type are still made.

The windings of these magnets are connected together, and the ends of the wires are coupled to the brushes in such a way that the field windings and the armature windings are " in parallel," as it is termed. Thus current generated in the armature can flow from the brushes either through the field windings or to the battery, or whatever may form the external circuit. The amount which flows through the field circuit will depend upon the resistance of that circuit, and the voltage generated by the armature.

A dynamo of the shunt type described, although the best of the simpler arrangements for our purpose, is not ideal. In normal use a tractor engine may run at anything from, say, 1,000 r.p.m. to over 2,000 r.p.m., and the dynamo being directly coupled to the engine, must undergo similar variations of speed. This entails corresponding changes in the rate at which each conductor on the armature cuts the lines of force in the magnetic field, and there must consequently be a great rise in voltage as the speed increases. Any such result is undesirable because it would overload the lamps, battery and other equipment.

Special features are introduced to overcome this difficulty. They operate by reducing the strength of the field as the speed increases. Thus the higher rate at which each conductor passes through the field is offset by the weaker field, and the number of lines of force cut per second does not change much. This reduction of field strength is achieved by decreasing the current which flows through the field windings.

Output Control

Two quite distinct methods are in use to produce the desired result. The first of these to be employed is known as the third-brush system. In addition to the two main brushes, positive and negative, a third and smaller brush is placed between the main ones, and it is connected to one end of the field winding.

The maximum output of a dynamo depends very largely upon the position of the third brush with relation to the two others. By moving the third brush in the direction in which the armature revolves, a greater output can be obtained. There is, of course, a limit to the amount of current which the windings can safely carry, and for that reason it is certainly not advisable to push the output beyond the makers' recommendations. In the absence of these, however, a fairly safe method is to proceed as follows : Open the throttle to a point where the engine revs. represent the normal operating speed. The dynamo should then be generating its full output. If it is not, open the throttle a little more.

Switch on all lights and note the reading of the ammeter ; it should show a small amount of charge—about 2 amps. or a little less. If the needle is on the discharge side of zero, move the third (regulating) brush of the dynamo as required to obtain 2 amps. charge. Alternatively, if a charge of rather more than 2 amps. is shown in this test, the output must be reduced, as it will be too great when the lamp load is removed.

The method of arranging for brush movement varies with different dynamos. Sometimes there is a locking screw (or two screws) working in a curved slot in the end cover. The brush can be moved after slackening the screw (or screws) very slightly.

In another design, part of the brush carrier is formed as a toothed segment with which meshes a small pinion. A hexagon on the pinion enables it to be rotated with a spanner, thus moving the brush. A locking screw in the end cover prevents movement at the wrong time. There is a further scheme in which the brush carrier is frictionally held, so that only a fairly hard push is needed to move the brush.

On some types of dynamo the current can be further regulated by means of a hand-operated switch, which introduces resistances into the field circuit. As a rule there are two switch positions: "Charge" and "Half-charge." In the "Charge" position the normal output of the dynamo is generated; for "Half-charge" the amperage is reduced to approximately half the full rate. An additional resistance, which remains in circuit until the lights are switched on, may also be provided. By this means an excessive "daylight" charge is avoided, but the output is boosted up when the lamp load comes on.

In spite of third-brush governing, a voltage beyond the safety limit may be generated in certain circumstances; its effect would be to burn out the field coils. To guard against this, a fuse is provided in the field circuit. The field fuse will blow only if a fault develops in the main circuit, and it is a mistake merely to replace the fuse without finding the cause of its blowing. It is an even greater mistake to substitute a heavier-gauge fuse wire to prevent blowing. A fuse is a safety valve set to blow at a certain pressure, and any attempt to increase the "strength" of the fuse may lead to trouble.

If a dynamo and a battery be connected together and the dynamo be stationary, or running below its charging speed, the battery will feed back through the dynamo. This, of course, will result in the battery being discharged; therefore, an automatic switch (known as a cut-out) is placed in the circuit so that the current can be cut off whenever the dynamo is not generating.

The Cut-out

Its construction and working are simple. A soft-iron core carries two windings: one, the voltage coil, is of fine wire, with its ends connected across the dynamo terminals; whilst the other, of thicker wire and known as the current coil, has one end connected to a battery terminal. The other end is led out to a hinged soft-iron armature, which passes across the top of the core and carries a contact on its free end. The opposite, or fixed, contact is connected to a dynamo terminal. A tension spring holds the contacts apart when no current is flowing in the coils.

The action of the cut-out is as follows: When the dynamo is working a current flows through the voltage coil and magnetizes the core. The magnetic pull attracts the armature, causing it to overcome the tension of the spring ; thus the contacts close and allow the dynamo current to pass to the battery via the current coil. This increases the magnetic pull on the armature, so that the contacts are firmly pressed together, thus providing a free path for the current.

So long as the dynamo is running at charging speed the contacts remain closed, but when the voltage falls below that of the battery, as when the dynamo begins to slow down, the current reverses, passing from the battery to the dynamo. Thus there are two opposing currents acting on the cut-out windings, and their effect is to de-magnetize the core. This allows the armature to spring up so that the contacts open and stop the flow of current from the battery.

The contact adjustment must be accurately set if the cut-out is to work properly. Generally, the contacts close when the current reaches about .5 amp. and open when a reverse current of similar value passes.

Faults which can develop in a cut-out may consist of burnt-out windings, burnt or pitted contacts, or a sticking armature, due to the pull-off having weakened.

Burnt contacts can be trimmed by the use of a contact file, rubbed between them whilst the armature is pressed down gently. After trimming, it is necessary to see that the two points come together fully before the armature touches the cut-out core. Actually, with the points touching there should be a gap of .015 in. or so between the armature and the core.

Before touching the cut-out contacts, the battery leads should be disconnected from the terminal posts ; merely turning the charging switch to " Off " is not sufficient, as it breaks only the dynamo field circuit.

A weakened pull-off spring is an unlikely fault, but one not easily rectified, except by fitting a new spring obtained from the makers, as it is very difficult to find the correct tension by experiment.

In the case of burnt-out windings fit a new cut-out.

Momentary sticking of the contacts can sometimes be overcome by jarring the casing ; the fact that they have separated will be indicated by the needle of the ammeter returning to zero.

It must be understood that a cut-out is simply a safety switch which connects the battery to the dynamo for charging purposes, but it does not disconnect it when a state of full charge is reached ; thus it is possible, in certain circumstances, to overcharge the battery.

A battery can be maintained in perfect condition only when it receives a properly regulated charge, and this is a requirement which a dynamo of the third-brush type cannot fulfil, although intelligent use of the hand-controlled charging rate switch can do much to approach perfection.

Voltage Regulators

There is, however, another type of dynamo which regulates the charging current more accurately. The dynamo is similar to a third-brush machine in external appearance, but it is wound differently and the third brush is omitted. There are, in fact, only the two main brushes—positive and negative. The output of the dynamo is controlled by a regulator unit which has combined with it a junction box and a fuse box. The regulator causes the dynamo to give an output which varies according to the state of charge of the battery. If the battery has been discharged, the dynamo gives a high output, so that a normal state of charge is reached in a minimum time. If, however, the battery be fully charged, the regulator cuts down the dynamo output so that only a trickle charge passes to the battery, just sufficient to keep it in good condition without risk of overcharging.

In addition to controlling the rate of charge of the battery, the regulator provides for an increased dynamo output to balance the current taken by the lamps or other accessories whenever they are in use.

There is no charging switch, as the apparatus is entirely automatic ; moreover, the lamps are always supplied with their rated voltages, and there is no risk of their being burnt out owing to a faulty battery connection.

The voltage regulator consists of a cylindrical steel shell containing two windings through which passes a core or armature carried on a pair of guide springs. At each end of the core is a pair of contacts, one of which serves to insert a resistance in the field circuit, whilst the other pair short-circuits the field windings. The first pair of contacts is held closed by means of a spring when the regulator is not working.

The windings consist of a voltage coil, connected directly across the dynamo terminals, and a current coil which carries the full current from the dynamo to the battery. When the dynamo voltage reaches a predetermined figure, the magnetic field set up by the voltage coil becomes sufficiently strong to attract the spring-mounted core. This causes the first set of contacts to open, thereby inserting the resistance in the field circuit.

The resulting reduction in field current naturally lowers the dynamo voltage, and this, in turn, weakens the magnetic field set up by the voltage coil ; thus the core is allowed to return to its original position where it closes the contacts and so allows the voltage to rise to the predetermined maximum. The cycle is then repeated, and so rapid are the changes that the core is set into vibration, the amplitude increasing with the speed of the dynamo above that at which the regulator comes into operation.

When the vibration of the core is sufficiently high, the second pair of contacts comes into operation and short-circuits the field-winding of the dynamo ; thus the initial movement of the core inserts a resistance in the field-windings, whilst additional movement short-circuits the windings entirely.

The current coil of the regulator provides a means for compensation, as without it there would be a risk of overloading the dynamo when the battery is in a low state of charge. The winding assists the voltage coil so that when the dynamo is delivering a heavy current into a discharged battery the regulator comes into operation at a somewhat reduced voltage and limits the dynamo output accordingly.

Servicing the Dynamo

Dynamos, whether of the voltage-regulator or third-brush type, require a little maintenance attention from time to time, and this is mostly in connection with the commutator and brush gear.

After long service the commutator will become blackened on its surface and perhaps scored slightly, whilst the mica strips which insulate each of the commutator bars or segments may tend to project slightly above the general surface. These are conditions which lead to faulty working, as the projecting micas shown in Fig. 62 prevent the brushes from making proper contact with the commutator bars, and this, whilst cutting down the output, will also lead to bad sparking, with consequent burning of the commutator and brushes.

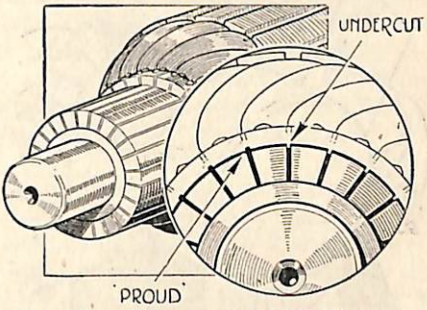


Fig. 62. When servicing the dynamo, projecting mica strips on the commutator should be pared down carefully as shown above.

The mica strips can be cut down by careful manipulation of a suitable tool, such as a very fine hacksaw blade, but it is necessary, of course, to remove the armature from the dynamo casing in order to gain access to the commutator. Withdraw the brushes first and then unscrew the cover at the driving end of the machine and pull out the armature. Clamp it gently in a vice, the jaws of which are protected by lead or fibre clamps.

If a lathe is available, mount the armature between the centres and bolt a narrow parting tool sideways in the toolholder so that when the saddle is moved along the bed the tool will operate on the mica after the fashion of a planer.

Only a slight undercut is necessary—that is to say, the mica strips should lie about 1/32 in. below the copper surface. The bottom of the cut should be square and not V-shaped. When the cutting is finished the surface of the commutator can be polished by use of very fine glasspaper. Emery cloth should never be used, as the grains of emery may bed themselves into the commutator and cause rapid brush wear.

If the armature is badly pitted or burnt, it may be necessary to skim it up in a lathe, but a very fine cut should be taken—only just sufficient to remove the pitting. Naturally, if this be necessary, it will be done before the micas are undercut.

When the armature is refitted to the dynamo it will be necessary to bed-in the brushes on the new commutator surface. Their working faces should first be examined : if they are bright and with fairly clean-cut edges they will require very little attention, but chipping or pitting will indicate the need for re-surfacing.

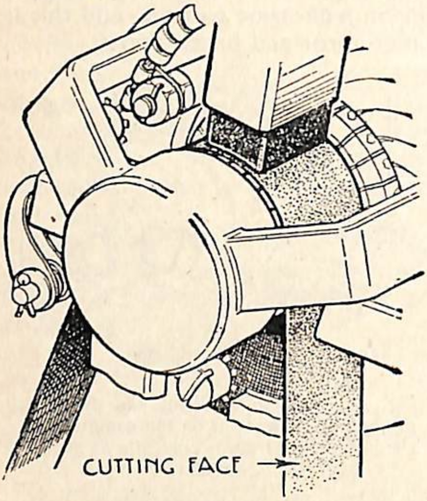


Fig. 63. Bedding-in the carbon brushes with a strip of fine glasspaper.

The best way to do this is to pass a strip of fine glasspaper around the commutator with the cutting surface outwards, as in Fig. 63. Each brush in turn is then slipped into its holder, with the spring pressing on it, and the glasspaper pulled backwards and forwards around the radius of the commutator. This will cut the brush face to the correct curve, as the thickness of the glasspaper may be disregarded.

When all of the brushes have been treated in this manner, a soft-haired brush should be used to clear away all traces of carbon dust which might otherwise cling to the brush-holders and perhaps set up short-circuits. Another good way of clearing carbon dust is to use a tyre pump, moving the nozzle about inside the brush casing and pumping vigorously.

The brushes must move freely in their holders, but no attempt should ever be made to increase the tension of the retaining springs, unless this be done in an emergency. Some makes of dynamo have three positions for the spring, each of which alters the tension and thus allows for maintaining a reasonably constant pressure as the brushes wear down.

Experience is necessary, however, to know which tension should be used, and it may be said that, normally, the lightest pressure on the brush consistent with proper contact and absence of sparking should always be adopted, as excessive pressure leads to rapid brush wear.

The clamping screws which hold the brush leads and the field-winding connections must always be tight, and there should be no free strands of wire which might cause a short-circuit. Dynamo brushes are made of a special form of carbon, and when brush replacement is necessary the correct type for the particular machine must always be used. The hardness of the carbon varies according to the special requirements, and great harm can be done by using brushes of the wrong grade.

The leads are secured to the brushes in various ways. If a lead should break away from the brush, it can often be successfully re-connected by soldering. The method is first to copper-plate the upper half of the brush ; this is done by making up a copper sulphate solution in a jam jar and suspending in it a small piece of sheet copper.

A wire is twisted round the brush so that this also can be suspended in the solution. The ends of the two wires are connected to a small battery, the copper to the positive terminal and the brush to the negative. In a few minutes a layer of copper will be deposited on the carbon brush, which can then be removed and washed in clean water. When dry, the lead can be soldered to it, and will hold securely.

The bearings of the armature are almost invariably of the ball type and require very little attention. It is important not to overdo the lubrication, as grease will certainly cause trouble if it gets on to the brush gear. In dynamos of more recent design, the bearings are packed with grease at the time of manufacture, and this supply is sufficient to last for a long time.

Exposed terminals must be kept clean and tight. Never connect any additional lead directly to the dynamo terminals : a wrong connection can easily cause a short-circuit which may burn out the windings.

XVII

STARTER MOTORS

A STARTER motor is similar to a dynamo in its general construction in that it has field windings, an armature, a commutator and brushes. There is a difference in the windings, however, as the fields are connected in series with the armature instead of being in shunt as in a dynamo, and there are usually four poles in a starter motor, whereas a dynamo now generally has only two. In order to cope with the very heavy starting current the brushes are usually duplicated so that there are two positives and two negatives.

Also because of the heavy current involved, copper strip is commonly used instead of wire for the windings of both the armature and the field magnets. The strip is, of course, insulated in much the same way as is the wire used in a dynamo, but the cross-section of copper is greater in relation to the space occupied by the insulation and thus a larger amount of conducting material can be built into a motor of given size. Much the same result could be obtained with large-gauge wire, but it would not be so easy to wind into shape.

A series-wound motor has the property of exerting its maximum turning effort when starting from rest, and this is just what is required when a sluggish engine has to be rotated. As the speed of the motor rises its torque or turning effort is reduced, with corresponding reduction in current demand ; thus, whereas at the instant of closing the switch there may be a drain on the battery to the extent of, perhaps, 200 amps., the current will drop to, say, 30 amps. within one second, and the motor will continue to rotate the engine at a speed which depends upon bearing stiffness, oil viscosity and so on. If the starter pinion engages with the flywheel, but does not rotate the engine, the battery will remain almost directly short-circuited.

When the starter switch is closed the rush of current from the battery to the motor causes an appreciable voltage drop, so that a normal 12-volt battery may show only about 9 volts at the instant discharge.

It is of the greatest importance to avoid reduction in voltage as much as possible, and for this reason, heavy cables and connections are used between the battery and the starter. Ample wiring is necessary also to avoid overheating and, incidentally, because so large an amount of current has to be dealt with, the ammeter is not connected to the starting circuit, as a very heavy type of meter would be necessary to carry the 200 amps. or so that might pass.

Although the demand made upon the battery is high at the moment of closing the starter switch, the actual energy consumption is not really great. Assuming, for instance, that the battery is of 50 ampere/hr. capacity, and charged normally at 8 amps., the current used in one start could theoretically be replaced in about 8 secs.

The energy consumption depends, of course, upon the stiffness of the engine, and it can be shown that 40 per cent. or so more current will be needed to start an engine from cold than when it has reached a running temperature of, say, 85 degrees C. ; similarly, the speed at which the engine is rotated by the starter when hot will be considerably higher than when cold.

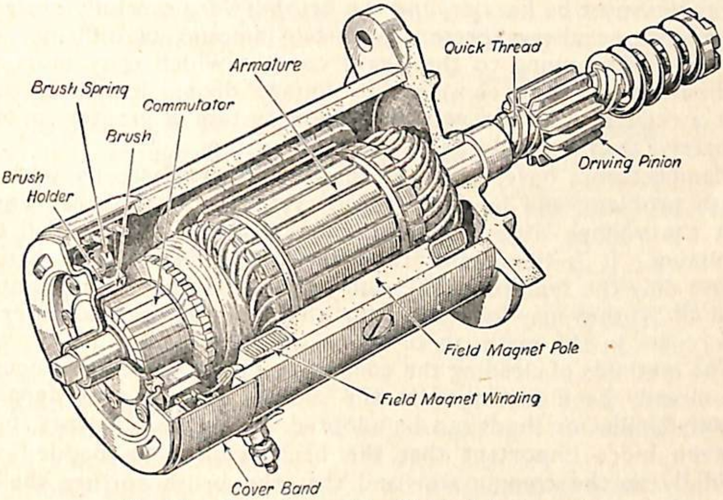


Fig. 64. General assembly of typical starter motor.

Every effort should always be made to use the starter sparingly. This does not mean that the engine should be cranked by hand, because starting systems are designed for use under all conditions, and if the battery, starter and engine be in proper working order, there should be no need to crank by hand.

If the engine does not fire within a second or two after pressing the starter button, it is a mistake to keep the starter engaged ; rather one should release the button and wait a few seconds, then try again. This gives the battery a chance to recover its voltage, whilst at the same time the mixture drawn into the cylinders will have had a chance to vaporize under the effect of the slight warmth set up by compressing the charges, even though they may not have fired.

Naturally, conditions can arise where the starter is definitely unable to cope with the load imposed upon it. This may happen in extremely cold weather when thick or gummy oil is used in an engine having, perhaps, rather tight bearings or closely-fitting pistons.

Considerable harm may be done to the battery and to the starter if the current be allowed to flow continuously while the engine is only just turning over. This is a case where the handle must be used, either alone or in conjunction with the starter, in which event, of course, an assistant will be necessary to press the button or to crank the engine.

From the actual power-output point of view, there is not much to choose between 6-volt and 12-volt systems, but, naturally, the current at 6 volts will be double that at 12 volts, and, other things being equal, the battery must have double the ampere-hour capacity, the cables must be heavier, and the brushes very carefully designed, because these always present a certain amount of difficulty in a starter motor owing to the heavy current which they must pass without causing any considerable voltage drop. It will be clear that a reduction of one volt in a 6-volt system is greater, proportionately, than it would be in a 12-volt system.

Manufacturers have, however, dealt very satisfactorily with the brush problem, and by using special grades of carbon can ensure that the voltage drop with either 6 volts or 12 volts shall be a minimum. It is important, therefore, when fitting new brushes to use only the type recommended by the makers. To the uninitiated all brushes may look alike, but there can be very considerable differences in the materials of which they are made.

The methods of cleaning the commutators and bedding-in brushes has already been described in the section dealing with dynamos. Exactly similar methods can be adopted with starter motors, but it is even more important that the brushes shall be bedded very carefully to the commutator and that the brush springs shall be properly set.

As a rule, the springs exert rather greater pressure than in the case of a dynamo, but as the starter may overheat in use there is a chance that the brush springs will lose their temper ; this, of course, will result in faulty contact with the commutator and consequent lack of power in the starter.

XVIII

BATTERIES

BATTERIES of the type used to operate starter motors and also those used in farm generator sets, are known as secondary cells. They do not actually store electricity, but they produce it through chemical change. The batteries discussed here are known as lead-acid batteries, because the essential constituents are lead plates which are immersed in a sulphuric acid solution (often called the electrolyte).

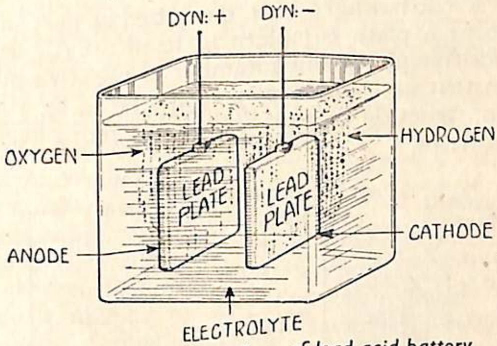


Fig. 65. The simplest form of lead acid battery.

In the simplest form, two lead plates can be placed in a trough of electrolyte consisting of about 10 parts of water to one of sulphuric acid. If a current is then passed through from one plate to the other for some time, one of them will acquire a surface of dark brown peroxide of lead, but the other will remain as plain metallic lead. The former is the positive plate and the latter the negative.

As constructed for practical use, the plates are not made of lead sheet. Instead, a lead grid is filled with a paste which, for the negative plate, consists of lead in a special spongy form. For the positive plate the grid is filled with a paste of lead peroxide. By

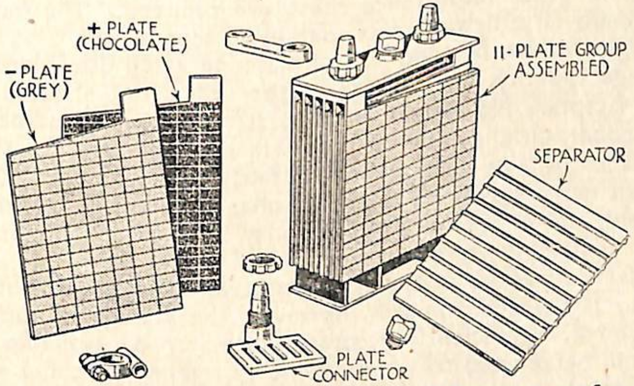


Fig. 66. The components of a single cell forming part of a starter battery.

using plates which are comparatively porous, the effective surface is largely increased, and thus a given size of plate is capable of storing a greater amount of energy.

It has already been indicated that the storage capacity of a cell depends upon the size of the plates, and as a considerable capacity is needed for starting an engine, very large plates would be required. To avoid this, the large plate is, so to speak, divided into a suitable number of smaller ones, all joined together in a cluster with spaces between the individual pieces. Both positive and negative plates are treated in this way, and the two clusters are, as it were, interleaved.

What has here been described as part of one big plate is referred to as a plate complete in itself. Each cell thus has a number of positive plates and a number of negative plates sandwiched together so that each positive surface is faced by a negative one. In modern construction there is always one more negative plate than there are positive.

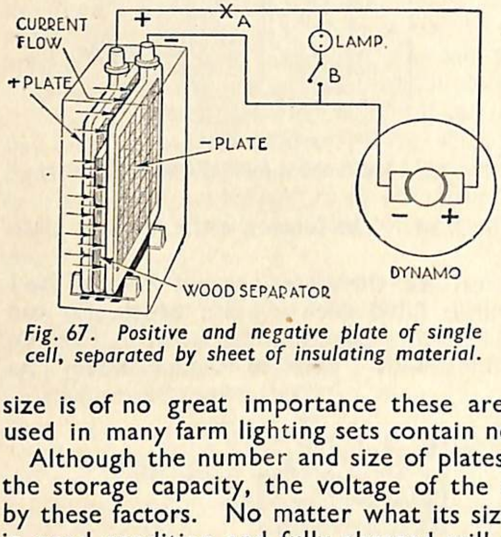


Fig. 67. Positive and negative plate of single cell, separated by sheet of insulating material.

If a negative and a positive plate were to touch inside the cell, the result would be much the same as a direct short circuit outside the cell, and the cell itself would be ruined. To avoid this a sheet of some non-conducting but porous material is interposed between every pair of positive and negative surfaces, but where size is of no great importance these are omitted. The batteries used in many farm lighting sets contain no separators.

Although the number and size of plates in a cell does determine the storage capacity, the voltage of the cell is not affected at all by these factors. No matter what its size may be, a lead-acid cell in good condition and fully charged will show about 2.5 volts. If it is put into use, its voltage will fall fairly soon to about 2.3, and then much more slowly to 2.1 or 2 volts. Thereafter the drop is quite rapid, and at 1.9 volts the cell may be regarded for practical purposes as completely discharged.

These facts suggest a method of discovering whether or not a cell or battery is charged. In fact, however, the voltage is not a safe guide, even if a sufficiently accurate voltmeter be available. The reading can be affected to some extent by temperature and also by the amount of rest a cell has had before the voltage is read. Thus a cell which is almost " dead," but from which no current has been drawn for some hours can show a quite misleading voltage for a short time before relapsing to something representing its true state. For these reasons, a safer guide to the state of charge or discharge is to be found in the density or specific gravity of the electrolyte.

The voltage of a battery, then, depends primarily upon the number of cells in it, and, secondarily, upon the state of charge of those cells. The capacity, on the other hand, depends upon the number of plates in each cell, and their size. This quantity is quoted in terms of "ampere-hours." This means simply the number of amperes which a battery will deliver and the number of hours for which it will continue to do so. Thus a battery which will supply 10 amps. for 5 hrs. would be a 50-amp./hr. battery, as also would be one that supplies 2 amps. for 25 hrs.

In practice a slight complication occurs, for it happens that the capacity of a battery depends to some extent on the rate at which it is discharged. Broadly, it is true that for very low rates of discharge there is practically no change in the capacity. Thus a battery which could give 1 amp. for 50 hrs. would probably also give 2 amps. for 25 hrs., but it would almost certainly not give 10 amps. for 5 hrs., and it could not maintain anything like 50 amps. for 1 hr., although all these various combinations are numerically equal to 50 amp./hrs. For that reason, the capacity of a battery is always coupled with the discharge rate, as, for instance, "50 amp./hrs. at the 10-hr. rate," which means that this battery when fully charged will deliver 50 amp./hrs. if discharged in 10 hrs. or more, but the same capacity must not be expected if the battery is discharged in less than 10 hrs.

In normal batteries the capacity is some indication of the proper rate at which the battery should be charged, but even that is scarcely true for tractor batteries which have been developed to withstand discharge rates that would wreck many cells. This quality in them permits, also, of charging at a higher rate than would usually be safe.

It is a mistake to charge always at a high rate. In this connection many drivers believe that use of the starter motor so drains the battery of current that continuous full-rate charging for a length period is necessary to make good the loss. This is a fallacy.

If a quick start be obtained, the current used will be replaced by the dynamo in about half a minute, whilst, even if the starter has to be used several times before the engine fires, 5 mins. should be ample for replacing the used current.

It has been stated that the elements of a charged battery are a surface of metallic lead on the one hand, a surface of lead peroxide on the other, and a dilute solution of sulphuric acid in between. During discharge and during charge a current flows through the acid, and therefore the water in it is electrolysed or split into its components, oxygen and hydrogen. While the cell is being discharged, the oxygen thus liberated appears at the lead surface, where it first forms the simple oxide of lead, and this in turn is acted upon by the acid to form lead sulphate. This second reaction results also in the formation of water, which is, so to speak, a waste product left over when part of the acid has been combined with the lead oxide.

At the other plate which has a surface of lead peroxide (not to be confused with lead oxide), hydrogen appears. This reduces the lead peroxide to lead oxide by robbing it of part of its oxygen, which, when combined with the hydrogen, forms still more water. The lead oxide in this case, as in the other, is converted by the acid into lead sulphate, and a third addition of water occurs. Thus, when the cell is completely discharged, both surfaces consist of lead sulphate, on which the acid has no further action. Incidentally, the acid itself has been considerably weakened by the addition of water generated during discharge in the manner stated.

Battery Charging

Now consider the reverse process—charging. As stated, electrolysis occurs again, but, because the direction of current flow is reversed, hydrogen instead of oxygen appears at the surface, which was originally metallic lead. There it combines with the sulphate to form sulphuric acid, leaving the lead free by itself again. At the other plate oxygen appears where there was hydrogen during discharge. This oxygen, together with some of the water from the acid solution, combines with the lead sulphate to form lead peroxide and sulphuric acid again. Thus the final state is the same as the original.

Before starting this description of occurrences inside a cell it was remarked that to overcharge a battery may be harmful. From the description already given, it will be realized that when the cell is fully charged the electrolyzed oxygen and hydrogen can no longer combine with lead sulphate because there is none left on either plate. Both the oxygen and the hydrogen escape by bubbling up through the acid and passing out of the vent plug at the top of the cell. (If the cell has a glass or celluloid case, as many have for wireless use, for example, these bubbles can be seen plainly when charging is complete.) A result of this is that some of the water of the electrolyte is permanently lost, so that the solution becomes stronger and smaller in quantity. It is thus neither of the most desirable strength nor of sufficient depth to cover the plates completely.

For this reason pure water must be added from time to time, so as to replace the water lost by electrolysis. Emphasis must be placed on the fact that water only and not acid is lost in this way. Therefore water only must be added, unless it is known that some of the electrolyte has actually been spilt or has leaked through some flaw in the cell case.

When the plates are discharged they are coated with lead sulphate. At the time of formation this compound is comparatively soft and porous, and it can be attacked by the oxygen and hydrogen during re-charging. If allowed to stand, however, it hardens and becomes scarcely penetrable. Normal charging then is almost impossible and much trouble is needed to bring the cell back into a useful condition. In extreme cases this may even be quite impracticable, and a new battery or new plates will then be necessary. The trouble is known as sulphation, and the treatment for mildly sulphated plates will be described later.

The state of charge of a battery can be gauged by measuring the strength of the acid in it. During discharge, as has been seen, water is formed and is added to the acid, which thus becomes weaker, but during the charging process acid is formed and the original strength is restored.

Sulphuric acid is considerably heavier than water (more than five times as heavy in its concentrated form), so even the dilute solution used in a cell has a density appreciably greater than that of water, and if it is diluted still more its density is reduced correspondingly. If a little electrolyte is drawn into an instrument known as a hydrometer, one may compare the weight of the fluid with that of pure water by a direct reading.

Testing Electrolytic Density

Differing battery makers have at various times followed slightly different practices in the choice of electrolyte density. The correct figure should, therefore, be taken from the maker's instruction book, if that is available. Generally, however, the density when a cell is completely charged should be between 1.25 and 1.3. (These figures mean simply that the weight of, say, a pint or a cubic centimetre of the liquid is 1.25 times or 1.3 times the weight of the same volume of pure water.) When the cell is for practical purposes completely discharged, the density should have dropped to about 1.15.

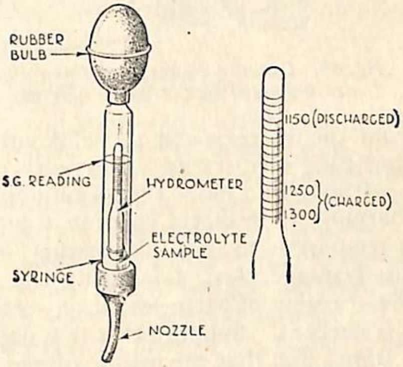


Fig. 68. A hydrometer or calibrated float is used to measure the density of the electrolyte. For convenience it is generally contained in a syringe with which a sample of the fluid can be drawn from the cell.

When using a hydrometer there is one precaution it is wise to take. If distilled water has recently been added, and in certain other circumstances, the liquid may not be of equal strength throughout. To mix it up, the bulb should be released and squeezed firmly several times while its tube is still submerged. In this way currents of liquid can be squirted through the cell so as to stir the electrolyte and mix it thoroughly.

If one or more of the cells shows considerable variation in specific gravity from the others, it is a sign that some fault has developed, and a proper examination by a service station is desirable. Sometimes the necessary correction can be made by adjustment of the specific gravity of the electrolyte, but it may be necessary to remove the plates from the cell for examination and renewal as required.

If a battery is allowed to stand for some time in a discharged, or even a partially discharged, state, the lead sulphate naturally formed on the surfaces of the plates will harden, and this will reduce the usefulness of the battery. Moreover, it will also increase the resistance inside the battery, and, if any attempt be made to recharge at a high rate, the result must be to heat the plates and possibly to buckle them. To cure the trouble, the battery must be re-charged very slowly, and it is probable that a single charge will not complete the cure. Therefore, after charging slowly, the battery should be discharged also at a slow rate. This sequence should be repeated several times. Even that treatment will be insufficient if sulphation has become at all bad. In such cases the first step should be to empty the electrolyte from the battery and to refill with a very much weaker solution consisting of distilled water with only a trace of acid in it.

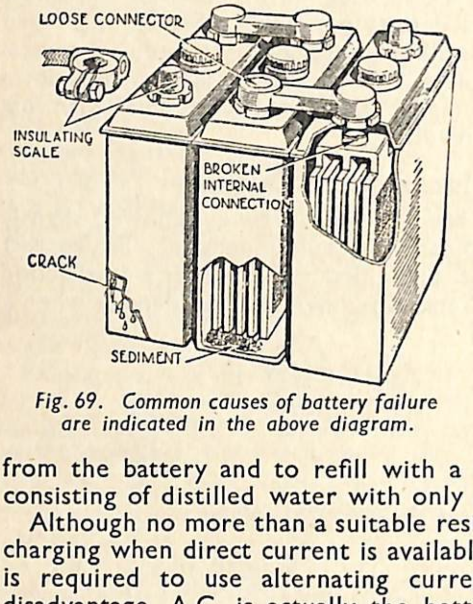


Fig. 69. Common causes of battery failure are indicated in the above diagram.

Although no more than a suitable resistance is needed for battery charging when direct current is available, more elaborate apparatus is required to use alternating current. Despite this apparent disadvantage, A.C. is actually the better form of mains supply for the charging of batteries, at any rate on a small scale, because it uses less current. Suppose that it is desired to charge a 6-volt battery at 2 amps., and that the mains voltage is 220, the supply being by direct current. Sufficient resistance must be inserted to bring the voltage across the battery terminals down to about 8 volts, but the required 2 amps. must flow through the complete system, including the resistance, and thus the number of watts consumed is 220 volts multiplied by 2 amps., or 440 watts. Consequently, one Board of Trade unit would last for very little more than two hours.

By contrast, if alternating current mains are available, the consumption will not be immensely greater than 8 volts multiplied by

2 amps. If one reckons that the efficiency of the apparatus is as low as 25 per cent., the consumption from the mains is still only 64 watts, and therefore one B.O.T. unit would last for nearly 16 hours.

As we have seen, during charging the water in the electrolyte may be driven off, thus increasing density of the solution. The need for fairly frequent examination of the level of the electrolyte in the cells, therefore, becomes apparent and it is not carrying caution to excess to make the examination fortnightly. This is especially so in hot weather, or where the battery is mounted close to the engine, because natural evaporation due to heat is also to be considered.

Wherever possible, distilled water should be used for making up the level. The normal correct level of the electrolyte may be taken as $\frac{1}{4}$ in. above the tops of the plates ; the cells should never be filled so that the solution stands in the necks of the filling orifices, as this does not allow sufficient room for gassing or expansion.

It is important to keep the top of a battery perfectly dry, as the presence of moisture, especially if it be slightly acid, will set up terminal corrosion and may also permit current leakage between the cells. The stoppers of the filling orifice should always be screwed down tightly on their rubber gaskets and the terminals should be coated with petroleum jelly or with anti-corrosive grease.

The actual terminal lugs and busbars will not corrode, as they are made of lead, but the connectors and their clamp bolts are sometimes attacked by the acid. An effective and safe way of removing the corrosion is to soak the parts in a strong alkaline solution made by dissolving washing soda in warm water.

Repairing Battery Casings

Sometimes the top of a battery will crack and allow the escape of electrolyte, or, rather, of the vapour. As a general rule, it is advisable to return the battery to the makers for professional attention, but quite often a satisfactory repair can be made by first drying the top of the cell thoroughly and then melting together the edges of the crack by the application of a hot iron. Alternatively, the crack can be filed or scraped out to a V section, after which Chatterton's Compound is melted into it. Care should be taken so far as possible to prevent the filings from falling through the crack into the cell.

XIX

CLUTCHES

A CLUTCH is a device for engaging and disengaging the power developed by an engine to a gearbox or to a shaft, etc. In some clutches arrangement is made for a gradual link-up, and in others the power is either being transmitted in full or it is not being transmitted at all. Clutches of the first type are fitted to cars, lorries and tractors, but the second type, which is known as the dog clutch, is generally used on small machines, although sometimes both types are used, as they are on the Trusty.

Cone Clutch

The gradual-type clutch may be operated by either a pedal or a lever, or it may be controlled by centrifugal force. In the gradual-engagement clutch it is possible for one shaft to be revolving rapidly while the other is either stationary or turning at a lower speed. As the clutch engages, the speed of the two shafts becomes equal so that when the clutch is fully engaged, both shafts revolve as one.

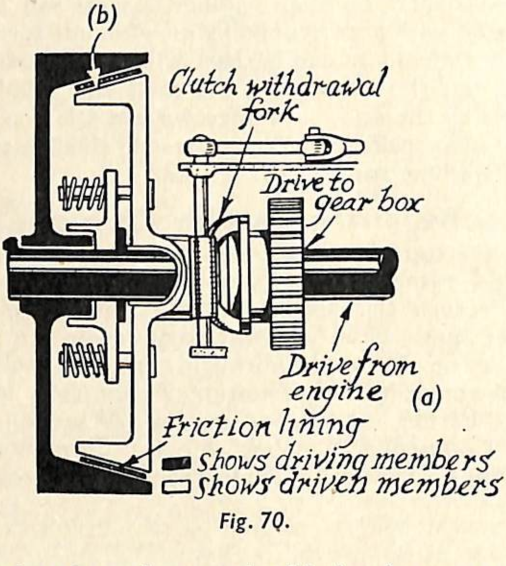


Fig. 70.

These clutches depend upon the friction between two or more surfaces, and the earliest form of this clutch was known as the cone, see Fig. 70. The portion marked (a) is driven by the engine, and is usually the flywheel with a machined recess. Part (b) is tapered as shown, the tapered portion being covered with leather or with a woven fabric of the Ferodo type. The part (b) is usually splined internally so that it slides along its shaft. A powerful spring normally presses the two parts closely together, disengagement being effected by pressing a pedal and contracting the spring.

Plate Clutch

Modern clutches, however, are generally of the plate type, a simple example of which is shown in Fig. 71. " A " represents the flywheel, which is bolted to the engine crankshaft. Screwed into this are a number of bolts " B." Sliding on these bolts is a thick plate C, which revolves with the flywheel, although it can take up position either close to or a few inches away from the flywheel face.

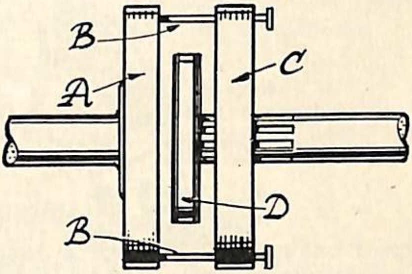


Fig. 71. A simple type of plate clutch.

Interposed between these two plates is another plate D, which is splined on a shaft connecting to the gearbox. Both sides of this plate have a friction disc riveted to them. The clutch is operated by pressing the plate C towards the flywheel so that it binds onto plate D and pushes it into contact with the flywheel face. There are thus two areas of friction, that between the flywheel and plate D, and that between the other side of D and the plate C. Springs hold the clutch plates tightly together, and a pedal mechanism enables the plates to be separated and the drive disengaged.

Servicing a Borg and Beck Clutch

Fig. 72 is a sectional drawing of a Borg and Beck single-plate clutch which is essentially the same in principle as that described above, and as this make of clutch is fitted to so many different types of vehicles and tractors, some information on servicing it will be useful.

The only maintenance required by the clutch is the periodical greasing of the withdrawal bearing and adjustments described below. To adjust the clutch travel pedal, release the lock-nut on the pedal rod and tighten the adjusting nut until the pedal is in its original position, which is usually when there is 1 in. of free play in the pedal before it starts to take up the strain of operating the clutch. Different manufacturers have their own methods of measuring this amount of free play—for instance, in the David Brown tractor it is " when the front edge of the pedal is approximately 3 ins. behind the corner of the trough of the main frame and all free movement is taken up."

On the Fordson Major the instructions are : " Remove the cotter-pin from the clevis-pin, loosen the lock-nut, and then pull out the pin, which will enable the clevis to be freed from the balance lever. Screwing the clevis further on to the rod will reduce free movement. When approximately $\frac{1}{2}$ in. free movement exists, fit a new cotter-pin in the clevis-pin and re-tighten the lock-nut." The main thing to remember is that unless there is a certain amount of free pedal movement there is a likelihood of the clutch not bedding properly, resulting in slip and the generation of considerable heat.

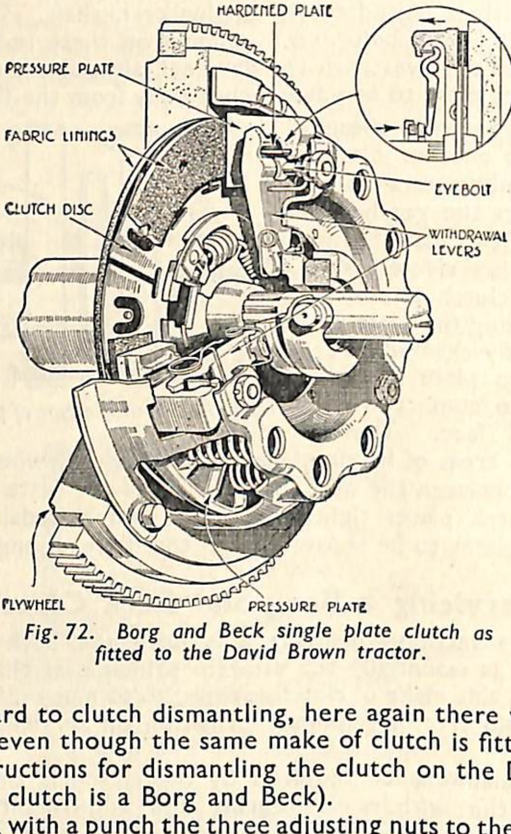


Fig. 72. Borg and Beck single plate clutch as fitted to the David Brown tractor.

With regard to clutch dismantling, here again there will be slight differences, even though the same make of clutch is fitted, but here are the instructions for dismantling the clutch on the David Brown tractor (the clutch is a Borg and Beck).

First mark with a punch the three adjusting nuts to their respective eyebolts, then remove the split pins. Place the unit on the bed of a drill press, with a block under the pressure plate, so leaving the cover free to move downwards.

Place a block square across the face of the cover and under the spindle of the press and then compress the cover and hold it in this position while the adjusting nuts are removed. Then slowly release the pressure to prevent the springs flying out. Lift off the cover, when all parts will be available for inspection. To remove the toggle levers, hold each lever and eyebolt between the thumb and finger, so that the inner end of the lever and the threaded portion of the eyebolt are held together, keeping the eyebolt seated in the socket in the lever. Lift the strut over and away from the end of the lever, when the lever and eyebolt can be removed.

Assembling is the reverse of dismantling, but before assembling the levers, smear the eyebolt pin and strut seatings with a thin coat of high-melting-point grease, and position the centre plate so that the flange of the hub is toward the rear. Satisfactory operation of this type of clutch is absolutely dependent upon accurate adjustment of the levers so that the pressure plate is parallel to the flywheel face. When renewing levers, struts, eyebolts or pressure plate, it is advisable always to assemble with new eyebolts and adjusting nuts and to use a setting gauge (this is obtainable from the manufacturers of the tractor) for obtaining the correct adjustment.

Centrifugal Clutches

Centrifugal clutches are simple to service, and the mechanic will soon see when he takes one apart how it should be assembled and what parts require lubrication.

Dog Clutches

With regard to dog clutches, one of these is fitted to the Trusty tractor—which, incidentally, has also a centrifugal clutch as well.

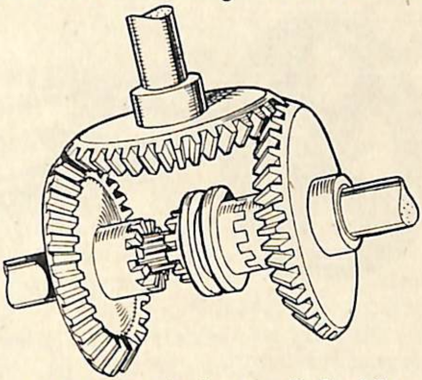


Fig. 73. Dog clutch as usually fitted for reversing the gear train on chaff cutters.

As the engine speeds up the centrifugal clutch engages and drives a layshaft on which there are two chain sprockets with chains to the rear-wheel shaft. Two long levers operate the dog clutches. The component parts of a dog clutch are two collars, one male and the other female, the former having one or more projections on one face of the collar, and the female having two corresponding cavities as shown in Fig. 73. It will be clear that when the two parts are disengaged, no power is transmitted from one to the other, but when the parts are in mesh, the full power is conveyed from the driving to the driven member. Because of this construction, dog clutches should not be operated unless both halves are stationary. Dog clutches are usually fitted for reversing the gear train on chaff cutters.

XX

FRONT AXLES AND STEERING

THE majority of tractor front axles are quite simple, consisting of the axle itself, which is prevented from forward or backward movement by a radius rod ; stub axles, which carry the wheels and bearings ; bushed spindles on which the stub axles pivot, and the control shafts. Steering control is through two steering arms, one controlling each spindle, each being connected to a spindle, and attached at the other end to a tie-bar. The nearside spindle has also an additional arm which is connected via a drag link to the steering-box and steering-wheel..

The Fordson Major steering arrangement is a typical example, and the accompanying illustration (Fig. 74) shows the various parts. In row-crop tractors there is a double axle, the second being in two parts, each of which may be moved in or out as required.

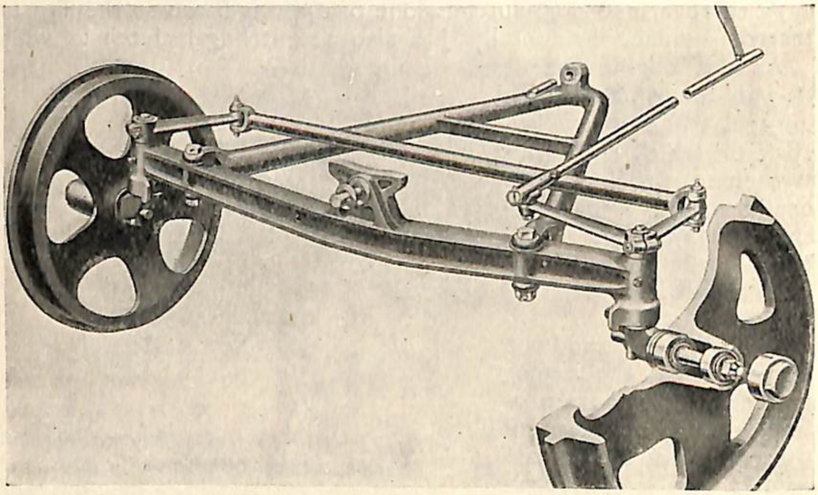


Fig. 74. Steering arrangement on Fordson major tractor.

Steering gear is generally based on the Ackerman principle, which permits the inner wheel on a turn to run through a smaller arc than the outer. This is not, perhaps, so necessary in a comparatively slow-moving vehicle, equipped with steel wheels and confined to work on farmland, but for road work, particularly where rubber tyres are used, it is essential that the wheels be arranged as described above.

Toe-in Adjustment

On most tractors the front wheels must point slightly inwards when the wheels are set to drive straight ahead. The actual amount varies a little according to the make, but it lies between $\frac{1}{8}$ in. and 3/16 in. Anything between these two amounts would be good enough as a temporary adjustment, but it is recommended that the figure given by the manufacturer be kept to, particularly for road work.

This difference is known as toe-in, and it is the difference in width between the front and back of the front wheels. A simple gauge for checking toe-in can be constructed from iron tubing, and it should preferably be in the lines of the drawing (see Fig. 75).

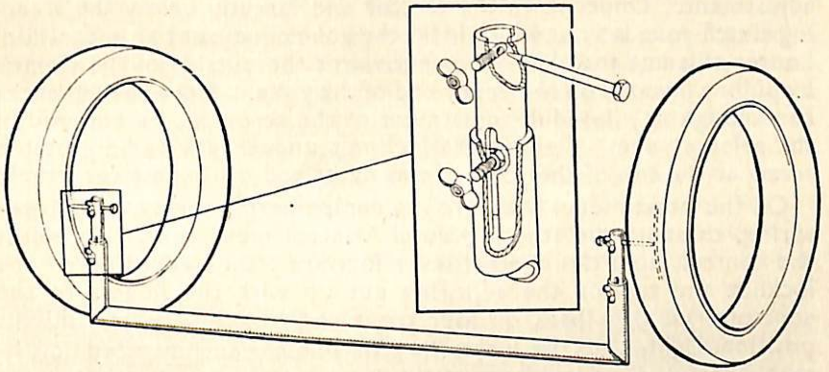


Fig. 75. A home-made gauge for checking toe-in of front wheels.

Each of the uprights carries inside it a smaller tube or a solid bar, and the height of this bar should be adjustable if more than one make of tractor is used or if steel and rubber tyres are available. One of the uprights is fixed to the horizontal bar, but the other should be adjustable. Adjustable pointers will enable accurate measurement, or rather comparison, to be made. To use the tool, run the tractor on to a level floor and set the wheels straight ahead. Slide the tool under the engine and adjust it so that the two pointers are at axle centre height, and that they both lightly touch the rim of the wheel or the wall of the rubber tyre. Without altering this adjustment, remove the tool and place it in front of the axle and note the difference between the two wheels. There should be a gap equal to the recommended toe-in. Adjustment varies a little according to the make of the tractor, but generally it is a matter of releasing the clamp bolts on the track-rod ball joints and turning the rod in the desired direction to lengthen or shorten the rod. Shortening the rod decreases the amount of toe-in. Always tighten the clamp bolts securely after the adjustment has been made.

Steering on Tracklayers

Tractors such as the Caterpillar, Fowler F.D., the Bristol and the Ransomes cultivator are steered by brakes, and it is essential that the correct adjustment be maintained. On the D.8, start by removing the inspection plate on the top of the transmission housing, then loosen the locknut on the clamp bolt, and turn the adjusting screw in towards the centre of the tractor to obtain the correct clearance on the steering control rods. The adjustment must be kept at a point that will allow 3 ins. of free play at the top of the steering clutch control levers. This applies to all Caterpillar tractors.

When all adjustment is taken up on the top of the steering yoke, the position of the yoke itself can be changed to allow for further adjustment. Underneath the tractor and directly below the steering clutch yoke is a nut which locks the yoke equalizer bar in position. Loosen this nut and slide the bar towards the outside of the tractor by pulling inwards on the upper end of the yoke. Move the equalizer bar enough to allow full adjustment of the screw at the top end of the release yoke. Tighten the lock-nut underneath and adjust the screw at the top of the yoke as was described in the last paragraph.

On the latest model D8 there is a compensating spring, or booster spring, to assist the steering-clutch control movement. To adjust the control, hold the control lever forward after slackening off the locknut and tighten the adjusting nut up with the fingers to the control arm, then back off four turns and holding the nut in this position, tighten up the locknut. The booster springs need adjustment when the control lever sticks in an upright position. Remove the inspection plate on the top of the transmission case (right hand cover for left-hand control, and vice versa), slacken the lock-nut and, with the control lever in the upright position, tighten the adjusting nut by screwing towards the back of the tractor until the lever moves forward. Give an extra half turn on the nut, hold it there, and tighten the lock-nut. The cross springs need adjusting when the control levers do not remain forward when released. To adjust, slacken the lock-nut which is located on the side of the transmission and under the seat, and tighten the adjusting nut. Test the control lever by pulling back and releasing it repeatedly. When the lever remains forward correctly when released, the adjustment is correct. Whilst holding the adjusting nut in position, tighten the lock-nut.

D7 and D6 Caterpillar Tractors

These have hydraulic steering. The control lever adjustment is done in the same manner as that described above, but the inspection cover is at the rear of the steering clutch case.

If at any time the steering clutches fail to re-engage properly, it is most likely that dirt or some object is lodged between the base of the control lever and the rubber bumper which is holding open the hydraulic control mechanism. Removing the obstruction should correct the difficulty. As the steering clutches become worn in service sufficiently to prevent restoring proper control adjustment, it is advisable to consult the Caterpillar tractor supplier.

D2 and D4 Caterpillar Tractors

The adjustment of the steering clutch controls is accomplished by means of lock-nuts and adjusting screws at the top end of the yoke, as already described on the larger machines. The inspection covers for this adjustment are on the top of the transmission case.

Bristol Tractor

Steering is accomplished by applying a brake in the form of a friction disc and after considerable wear it is necessary to renew the discs. To do this, first remove the petrol tank, and then take off the two nuts holding the cover on the outer face of the top steering bracket. These nuts are clearly seen marked B in Fig. 76. After removing the cover, take care not to pull the shaft and pinion out with it. Next remove the steering lever. On each end of the centre coupling rod the steering pressure plates are secured in position by locking nuts, one being right-hand thread and the other

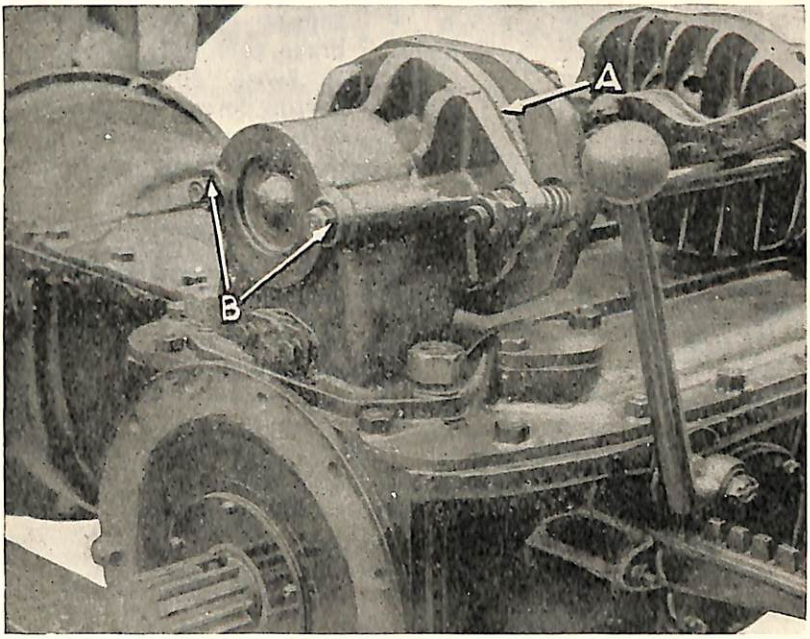


Fig. 76. Steering discs on Bristol tractor.

left-hand. Turn each nut anti-clockwise to the full extent of its travel, then by means of a spanner on the hexa-centre part of the coupling-rod, turn it anti-clockwise as far as possible. The pressure plates are in this way drawn inwards, and if the pinion is drawn out about ¼ in. there should be enough clearance to enable the disc to be drawn off the spline shaft and lifted out. It is important not to use force in drawing the pinion out beyond the point where a resistance is felt, as this will disturb the oil seal and oil thrower ring.

After the replacement discs have been inserted, adjust the coupling-rod until the pressure plates are just clear of the discs. The disc assembly should slide freely on the splines, but the discs should not rub. Then push the pinion back into full mesh and replace the end cap. When fitting the steering lever make certain that the clamp bracket permits equal and ample leverage for each individual application of the steering lever, either right or left.

Fowler F.D.3 Tractor

The steerage brakes fitted to the Fowler are of the contracting-band type, and to ensure sufficient clearance, a free pedal travel of 2 ins. is desirable. To adjust the brakes, remove the inspection cover D on the side requiring attention (see Fig. 77) and set by means of the adjuster E. To tighten the brake, turn the adjuster in a clockwise direction. Supporting screws are provided to prevent the brake band from bearing on the drum by its own weight. These screws are shown at F and G in the illustration, and they should be set to support the band in a central position. Do not overtighten them, as the band will be forced against the drum, causing binding and overheating.

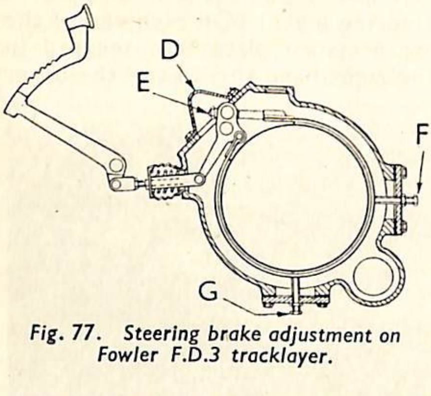


Fig. 77. Steering brake adjustment on Fowler F.D.3 tracklayer.

XXI

GEARBOXES AND REAR AXLES

THE transmission of power from a tractor engine to the rear wheels follows in its general principles the method used in the car and lorry. But because a tractor is designed for drawbar pull rather than speed, the gearbox parts are much more robust, and extra reduction gears are fitted. There is no carden shaft and no universal joints, for being a short-wheelbase vehicle, and having no axle springs, the final-drive mechanism, which includes the differential gear, is coupled direct to the gearbox.

The efficiency, in terms of power output, of an internal-combustion engine depends upon the maintenance of a good crankshaft speed, no matter what the r.p.m. of the rear wheels may be. Thus, when heavy loads have to be pulled, the only way to keep up the engine speed is to use gears, the ratio depending upon the resistance offered by the load. The gearbox is, in fact, merely a system of leverages, each gear change being equivalent to a longer or a shorter lever.

The Gearbox

The gearbox usually consists of a strong metal case or frame, the ends of which house the bearings for the gearwheel shafts. Means are provided for changing from one set of gears to the other, and, of course, there is a position (neutral) in which the engine power is not transmitted to the rear axle.

Tractor gearboxes vary considerably in design, and, in fact, no two are exactly alike. Because of this it is not possible to give detailed instructions as to dismantling. The mechanic who does undertake the task should endeavour to get as much information as possible from the tractor manufacturer, although in some cases he will merely be advised to send the unit to one of the firm's agents.

However, the best advice that can be offered him is to start by cleaning the box both externally and internally (it being assumed that the unit has been removed from the tractor) and then studying it carefully. With the cover off, one can soon trace the various gears, and if it is necessary to replace one of the wheels or a shaft, making a few sketches helps when re-assembling.

The majority of gear assemblies comprise a shaft drive from the engine, and carry on the rear end of the shaft a gear which is always in mesh with another and larger gear which is firmly attached to another shaft as in the following illustration (Fig. 78).

(A) Is the drive from the engine ; (B) the main drive gear ; (C) the layshaft (constant-mesh) gear ; (D) the layshaft. At (E) it will be noticed that there is a dog clutch, so that the shaft (F) can be driven direct by (A) if desired, although not all gearboxes have this clutch.

Both the shafts (F) and (D) are splined so that gears may slide along them, and it is, of course, the engagement of the various gearwheels which gives the necessary reductions.

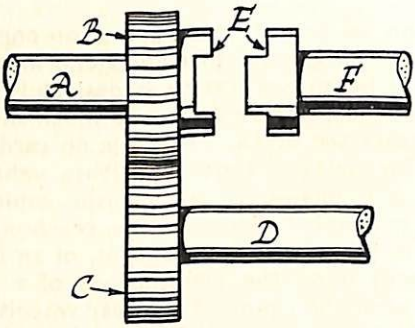
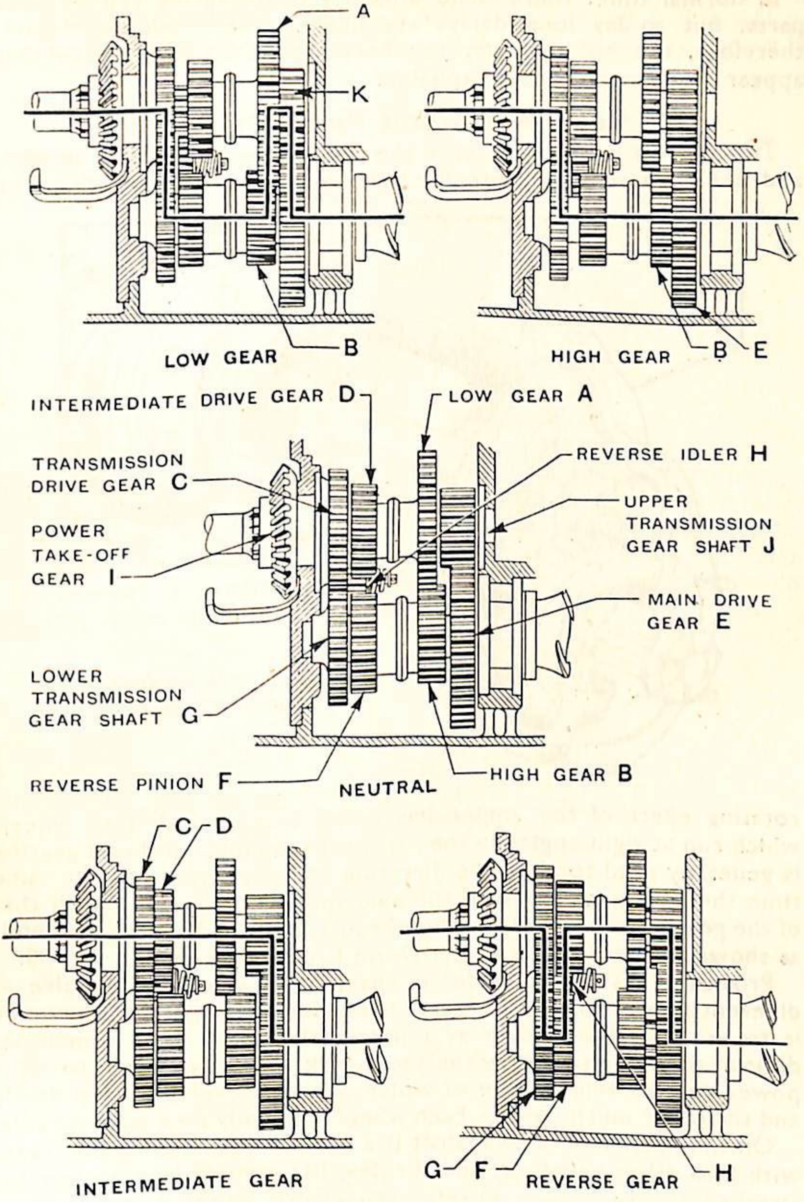


Fig. 78. Simple gearbox assembly.

Fig. 79 shows the various gear positions on a Fordson tractor, from which it will be seen that in low, high and reverse gears the drive is via the constant-mesh layshaft gear, and then through whichever gears give the correct reduction. In the intermediate gear, however, the dog clutch (E) in Fig. 78 is engaged so that the drive is taken direct by the shaft (F). The small gear at the rear end of this shaft engages with a larger one on the layshaft, and it is this shaft which is extended and provided with a worm gear that turns the worm wheel and the rear axle, as shown in the complete transmission. In this tractor access to the gearbox is obtained by separating the drive casing from the crankcase.

As has been said, no two makes of tractor gearbox are exactly alike, but nevertheless, the principles remain the same. The scope of the repair work that may be done even on the farm is practically unlimited, for it can include the fitting of any new part. The components of a tractor gearbox are, however, exceptionally strong and it is likely that the only work necessary will be fitting replacements and seeing that there is no undue play in the bearings.

In the absence of manufacturer's instructions, proceed slowly and do not attempt to force things. For instance, if two machined faces have to be separated, avoid inserting a wedge until you know for sure that the parts are free to come apart. Remove collars, ball bearings and plain bearings with a puller or a press, for these appliances are designed to distribute the strain and not concentrate it in one spot as does many an improvised tool. It must also be remembered that left-hand threads are not unknown, although generally a few minutes' thought concerning the type and direction of the strain will solve the problem of nut-turning.


A
K
B
B
E
INTERMEDIATE DRIVE GEAR D
LOW GEAR A
TRANSMISSION DRIVE GEAR C
REVERSE IDLER H
POWER TAKE-OFF GEAR I
UPPER TRANSMISSION GEAR SHAFT J
MAIN DRIVE GEAR E
LOWER TRANSMISSION GEAR SHAFT G
REVERSE PINION F
HIGH GEAR B
C
D
G
F
H

LOW GEAR

HIGH GEAR

NEUTRAL

INTERMEDIATE GEAR

REVERSE GEAR

Fig. 79. Gear train on Fordson Major tractor.

In normal times there is no difficulty in procuring replacement parts, but to-day long delays are likely. The mechanic should, therefore, use his ingenuity to effect repairs by any means that appear to be sound and reasonable.

Rear Axles and Final Drives

Tractor rear axles, too, serve the same purpose as those in cars, and their construction broadly follows the same principle. The rotating effect of the engine has to be communicated to wheels which run at right angles to the axis of the engine, and bevel gearing is generally used to alter the direction of the power. At the same time there is a reduction in the axle speed as compared with that of the gearbox shaft, and a further reduction is made at the axle ends as shown in the diagram of the David Brown rear axle in Fig. 80.

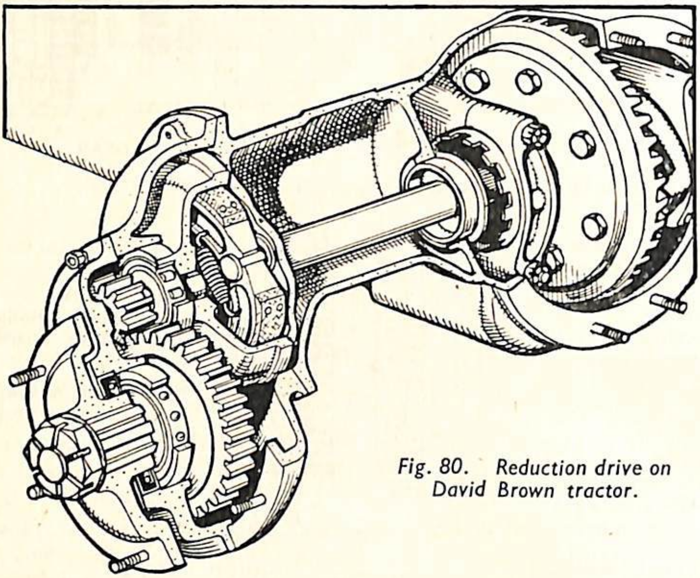


Fig. 80. Reduction drive on David Brown tractor.

Provision has to be made to enable the wheels to revolve at different speeds when the tractor is making a turn, and the practice is to use a device known as a differential gear. It is sometimes difficult to understand how this gear works, for it continues to apply power to two wheels, one of which may be revolving very slowly and the other much faster. Each wheel is actually on a separate axle.

On the inner end of each shaft is a bevel wheel, and each engages with two other bevels (a) and (b) (Fig. 81) mounted on projections attached to the crown wheel. The crown wheel is driven by a pinion which is rotated by the engine. (a) and (b) are free to rotate in their bearings, and of course, travel round with the crown wheel, but they do not revolve on their own axis.

When the axle bevels are engaged with (a) and (b) and the crown wheel is revolved, the whole assembly moves round as if it were a solid mass and there were only one axle, but when a resistance is offered to one of the shafts, such as when the machine is turning a corner, the bevel pinions (a) and (b) rotate in their bearings, so that although the whole mass still rotates and drives the tractor along, one rear wheel is actually being turned faster than the other, the amount depending upon the resistance. The resistance, of course, varies with the sharpness of the turn.

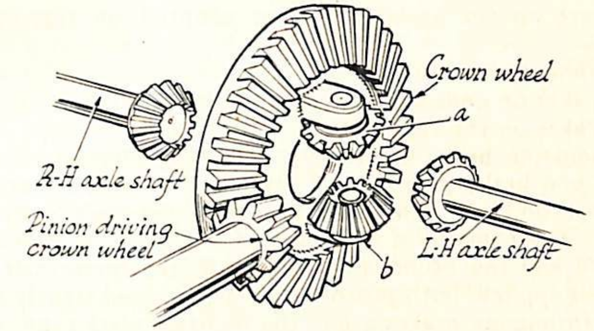


Fig. 81. Assembly of differential gear.

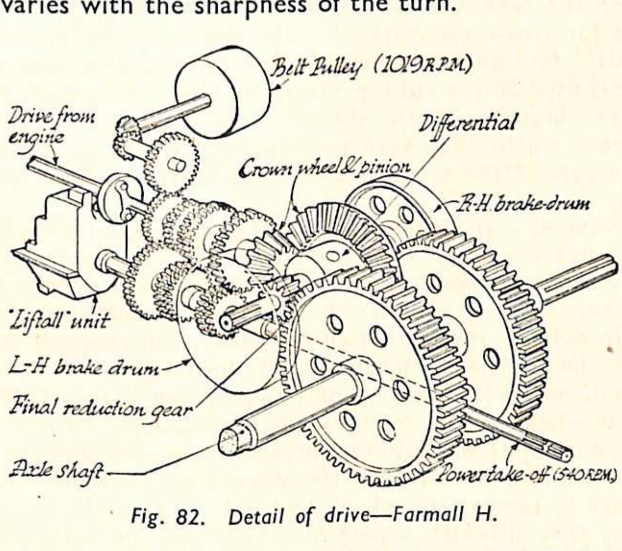


Fig. 82. Detail of drive—Farmall H.

As has been stated, not all tractor gearboxes and final drives are the same. In the Farmall H, for example, the final reduction gears are incorporated in the same unit as the gearbox, as will be seen in Fig. 82. These wheels are of the spur type, but in other tractors sprockets and chains are used.

XXII

TRACTOR BRAKES

THERE are various braking systems adopted on tractors, these being :—

(a) Transmission brake.
(b) Brakes on ends of a reduction shaft.
(c) Brakes on the rear wheels.

A transmission brake applies the retarding effort to a gearbox-shaft, the one brake giving equal retardation to both rear wheels. On the Fordson Major the brake is on the same shaft as the reverse idler gear, and consists of a number of steel plates, alternate ones being fixed and the others revolving with the idler shaft. When the brake is applied, both sets of plates are pressed tightly together. Not all transmission brakes are of the multiple-plate type, however, for some consist of a drum and a pair of fabric-covered shoes, which close on to the drum when the mechanism is operated.

Brakes on reduction-gear shafts may also be of this type, although some have shoes inside the drum, braking being effected by expanding the shoes as in most cars. Rear wheel brakes are generally internally expanding also.

It is now common practice to have independently operated brakes on the rear wheels of tractors—particularly those designed specially for row-crop work—for the brakes assist in turning on headlands. An interlocking trigger is often fitted so that when the machine is used on the road, pressure on one pedal only is necessary to put the brake on both wheels. One exception to this is the John Deere tractor, for here both pedals have to be depressed an equal amount if the tractor is to be brought to a stop without swerving.

In any event, it is highly desirable that each brake be adjusted to the same degree, as swerving is dangerous. Tractor manufacturers issue instructions about the adjustment of brakes on the machines they make, and as no two are the same, we cannot give them here. The main point is to see that all the pivots are properly lubricated and that the wheels are free when the pedal pressure is removed. In general, however, the method of equalizing brakes is to jack up both rear wheels of the tractor and then to apply a slight pressure to the pedal—just enough to put the brakes on a little. It will then be possible to compare the degree of resistance offered by each brake by turning the wheels by hand. It should be understood, however, that although a pair of brakes may be adjusted to give equal retarding effect at a light pedal pressure, it does not follow that they will be equal when the pedal is pushed right down. In view of this, readers are advised to have the brakes tested by an experienced man when the machine is to be used on the roads. Many garages have testing machines for this purpose.

XXIII

TYRES

RUBBER tyres consist of a casing made of cotton or other fabric covered externally with rubber. It is the fabric which provides the strength, and the rubber which protects the fabric and resists abrasion, weather, etc. The cover is held to its true shape by means of a rubber inner tube, and it is this which provides the necessary cushion to absorb shock.

As far as the mechanic is concerned, his work on tyres is generally confined to repairing punctured tubes, although he can lessen this by seeing that tyres are maintained at the correct pressure and that flints and stones are periodically removed from the tread rubber.

Danger of Under-inflation

A tyre that is under-inflated develops cracks all round the casing at a point midway between the tread and the bead, and although this cracking is not visible from the outside, it will, if allowed to continue, mean a burst cover which cannot be repaired. Too low an air pressure will also cause the cover to creep round the rim, and this frequently tears out the valve stem. On the other hand, over-inflation reduces traction and causes wheelspin under certain conditions.

The recommended pressures for front tyres depend upon the number of plies of fabric in the casing, for the greater the number of layers the stiffer the cover, so that it should be run at a higher pressure in order to prevent the same trouble as is caused by under-inflation. For four-ply covers, inflate to 28 lb. per sq. in., but for six-ply covers increase the pressure to 36 lb.

Tractor rear tyres are generally run at 12-lb. pressure, except for ploughing, when the tyre running in the furrow should be at 16 lb. The pressure should be still further increased when the tractor is used for road work.

When a cover—or any other rubber article for that matter—is manufactured, it is shaped in a soft, plastic rubber compound which has no tensile strength, wearing quality or elasticity. All these characteristics result from a process known as vulcanizing, or " curing," which is merely the application of controlled heat for a given period whilst the articles are held in a mould.

Methods of Tyre Repair

The same method has been used for many years by tyre-repair specialists, and in some garages, but vulcanizing is quite simple, and can be done in the field or in the farm workshop at very little cost. Patching has, of course, been customary for many years, and although it is moderately satisfactory with tyres made of natural rubber, it is not recommended for synthetic covers or tubes because this material does not adhere firmly to ordinary rubber solution.

There has recently been put on the market a small self-contained vulcanizing outfit which will repair tubes just as efficiently as the most expensive plant. The same materials and the same methods are used as in the rubber factory, the only difference being that individual heating units take the place of electricity. The outfit consists of a supply of vulcanizing compound (for use both on natural and synthetic rubber), heat units, buffing brush, vulcanizing flux, and a simple press which clamps the tube and compound tightly together during the curing process. A vulcanized repair takes very little longer than patching.

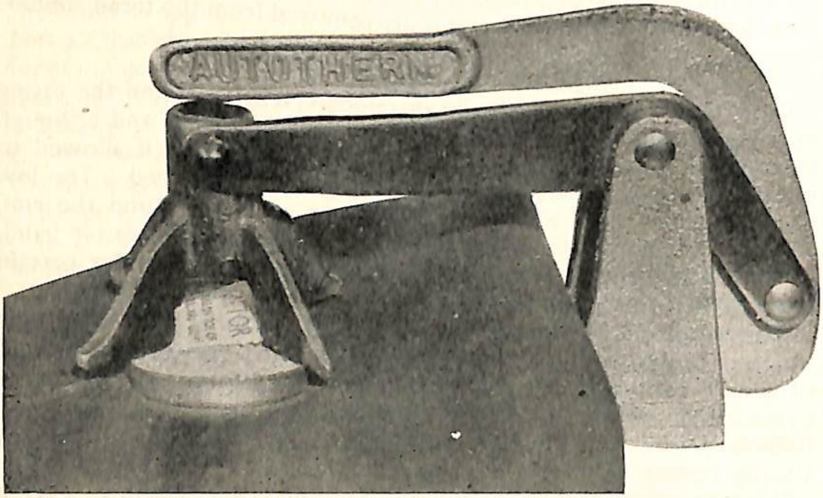


Fig. 83a. Autotherm vulcanizing press with heating unit in position.

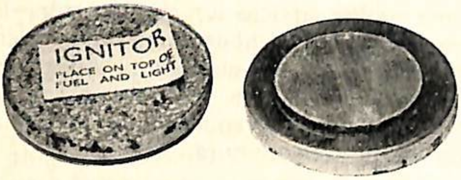


Fig. 83b. (Left) Top view of heater unit showing the compound. (Right) Underside view showing compound protected by a piece of glazed linen.

Fig. 83a shows the "Autotherm" press, and 83b two views of a heater unit. One of the illustrations shows the heater the right side up, and the special heating compound in its metal tray, and the other shows the underside with a piece of compound adhering to it. The compound is protected by a piece of glazed linen.

To repair a nail hole or a small cut in a tube, an area surrounding the injury is roughened with the wire brush just as in patching, although in this case the roughening is a little coarser. The surface thus treated is then given two coats of vulcanizing flux, each being permitted to dry. Vulcanizing flux is merely vulcanizing compound thinned out so as to penetrate every crevice of the roughened tube. A heater unit is then taken and the linen cover stripped off the compound, which is then (with the container) placed centrally over the injury and clamped in the machine.

The heater composition is ignited by placing on it a strip of "ignitor paper"—supplied with each heater—and lighting it with a match or a cigarette. The composition does not flame, but burns and generates heat to a temperature of 300° F. This heat softens the compound, which is forced into the roughened surfaces, and which later becomes welded to it. In five minutes or so the tube is removed and the repair is complete. The same process is used for synthetic rubber tyres, and in each case a permanent repair is assured.

Although the compound supplied with the appliance is cut to shape, it need not be used exactly like this. When, for example, a tube has received a cut or has been nipped when being replaced, the slit is likely to extend if patching is resorted to. To vulcanize this type of injury, first cut out the ends of the slit, using a sharp knife or a pair of scissors. Unless this is done the compound cannot get right into the ends and seal them firmly. Sometimes this is all that is needed, and the repair from then on is exactly as described above. Where, however, the slit is a long one, it is usual not only to cut the ends out, but also to bevel the sides of the slit, thus forming a V-shaped cavity all along the injury.

The wire brush is then used to roughen the bevel, and after the flux has been applied, a piece of compound (a quantity is supplied for the purpose) is pressed into the cavity until it is a shade above the level of the rest of the tube. If the tube is of natural rubber, the compound attached to the heater can be removed and the heater used to cure as already described, but for synthetics, the extra compound patch is applied over the filling. In this case it is, of course, necessary to buff the tube to accommodate it.

It frequently happens that an injury is longer than the heater unit, and in this case one would cure it piece by piece, allowing a small overlap to compensate for the reduced heat at the edges of the metal tray. Handled in this way, there is scarcely a limit to the length of the repair which can be done. It is even possible to completely rejoin a tube, although the process is likely to be long and one needing patience.

The machine described will not re-seat tyre valves, but the same firm make an electric appliance that will do this. The electric machine will repair longer injuries at one curing than will the "Autotherm," and it is an ideal tool for the farm with a mains electricity supply available.

Water Ballasting

Tractor tyres are frequently filled with water to give additional wheel weight and prevent wheel slip. It is necessary to render the filling non-freezing, and the most commonly used mixture is water and calcium chloride.

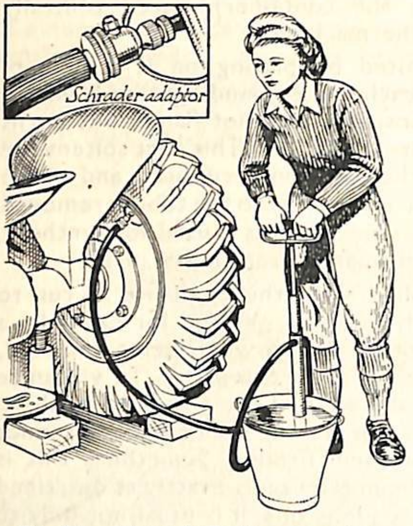


Fig. 84. Water ballasting tractor tyres with an ordinary stirrup pump and special Schrader adaptor.

A solution of 2½ lb. of commercial calcium chloride should be dissolved in each gallon of water. This mixture will form a slush at 10° above zero, but will not freeze solid at 20° below zero, and gives protection against 15° of frost.

The solution should never be mixed in the tyre, and the chloride should be sprinkled slowly on the water. On no account should water be poured on the chloride.

When the calcium chloride has dissolved, about 1 lb. of slaked lime per 100 lb. of calcium chloride should be slowly stirred in, to neutralize acidity. When sufficient lime has been added effervescence will cease. As soon as the liquid has cooled it may be pumped into the tyre with an ordinary stirrup pump, using a special adaptor obtainable for a few shillings from any of the leading tyre manufacturers.

The following table gives the quantities required for most sizes of tractor tyres :—

Size of tyre ins.	Water galls.	Calcium chloride lb.
11.25 by 28	28	70
11.25 by 24	25	62½
10 by 28	20	50
9 by 28	17	42½
9 by 24	13	32½

To part-fill the tyre, jack up the wheel and turn the valve to the top. Block the wheel to prevent it turning. Remove the valve core, allowing the air to escape, and replace the core with special adaptor. Connect the hose and commence to pump in the solution, releasing the air from the tube from time to time by pressing the knob in the special adaptor. Stop filling when the liquid can no longer be heard entering the tube—i.e., when the water has reached the level of the valve and the tube is three-quarters full. Remove the adaptor and replace with the normal valve core. Inflate the tube to about 30 lb. pressure to ensure that the tyre beads are re-seated in the rim. Reduce the pressure to 2 lb. per square inch above the normal working pressure to allow for the added weight. Be sure to wipe off all solution from the metal part of the wheel to avoid corrosion.

The solution is not dangerous, but may attack clothing or cause skin irritation. The remedy is to wash the skin with plenty of clean water.

XXIV

TRACTOR HYDRAULIC SYSTEMS

A TRACTOR hydraulic system consists essentially of a pump to provide oil under pressure, a piston, or ram, on which the oil pressure acts so as to lift the implement, and a control mechanism. The details of pump, controls and ram vary a good deal on different tractors, but any particular system can be readily understood once the principles have been grasped.

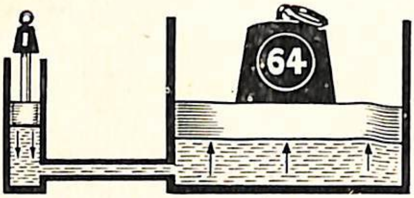


Fig. 85. Illustrating the fundamental principle of an hydraulic lifting system.

The fundamental principle—that the pressure is the same throughout a system containing fluid—is illustrated diagrammatically in Fig. 85. This shows a $\frac{1}{4}$-in. diameter cylinder connected to a 2-in. diameter cylinder, and, since the area of the latter is 64 times that of the former, it follows that a weight of 1 lb. on the small piston will support a 64-lb. weight on the large one. The pressure of the liquid is obtained by dividing the weight on one or other of the pistons by the area of the piston : it is actually 20.4 lb. per sq. in.

The Hydraulic Jack

The simplest hydraulic system in everyday use is the hydraulic jack which is illustrated diagrammatically in Fig. 86. The pump in this unit is, of course, hand-operated. It will be seen that the pump plunger is of small diameter compared with the ram, and so the effect shown in Fig. 85 is obtained. The force applied to the pump plunger is much greater than the downward force applied by the operator, due to the location of the plunger near the pivot of the operating lever. Thus there is a twofold magnification of the operator's effort, partly mechanical and partly hydraulic, with the result that he can very comfortably raise a load of 2 tons or more.

The system of control on the hydraulic jack is well worth noting, even if it is so simple as to be quite obvious, because the much more complicated arrangement on a tractor does essentially the same job. The pump has two non-return valves, one for suction and one for delivery. The force of pumping holds the suction valve on its seat when oil is being pumped into the ram cylinder, and the pressure of oil in the ram cylinder holds the delivery valve on its seat (and prevents the ram dropping) during the suction stroke. The only control that the operator has to manipulate is the valve to release the oil trapped in the ram cylinder whenever he wishes to lower the jack. The oil is returned to the reservoir from which the pump draws its supply.

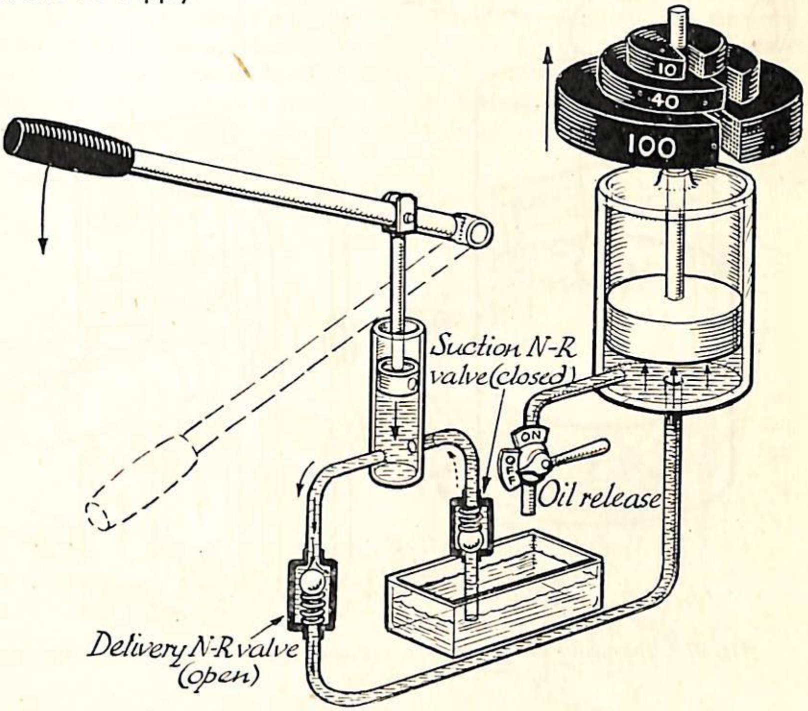


Fig. 86. Diagrammatic illustration showing the operation of an hydraulic jack.

The Power Pump

A tractor hydraulic system differs from the jack in that a power-driven pump provides the oil under pressure. A single-cylinder piston pump would not be satisfactory, since it would not give a steady supply of oil, and, therefore, when a piston-type pump is used it is a multi-cylindered unit with one cylinder after another delivering the oil. A typical pump of this type is illustrated in Fig. 87 It will be seen that there are four plungers mounted in opposed pairs, each pair being driven by a cam or eccentric. A little thought will show that two pairs are necessary since if there were only one pair one cylinder would not start delivering until after the first had stopped.

Another type of pump used is the gear pump, similar to that used for pressure lubrication in a car engine, and in many tractor engines. It is, of course, more carefully designed and more robustly built for tractor use, since the blow-off pressure in a tractor hydraulic system

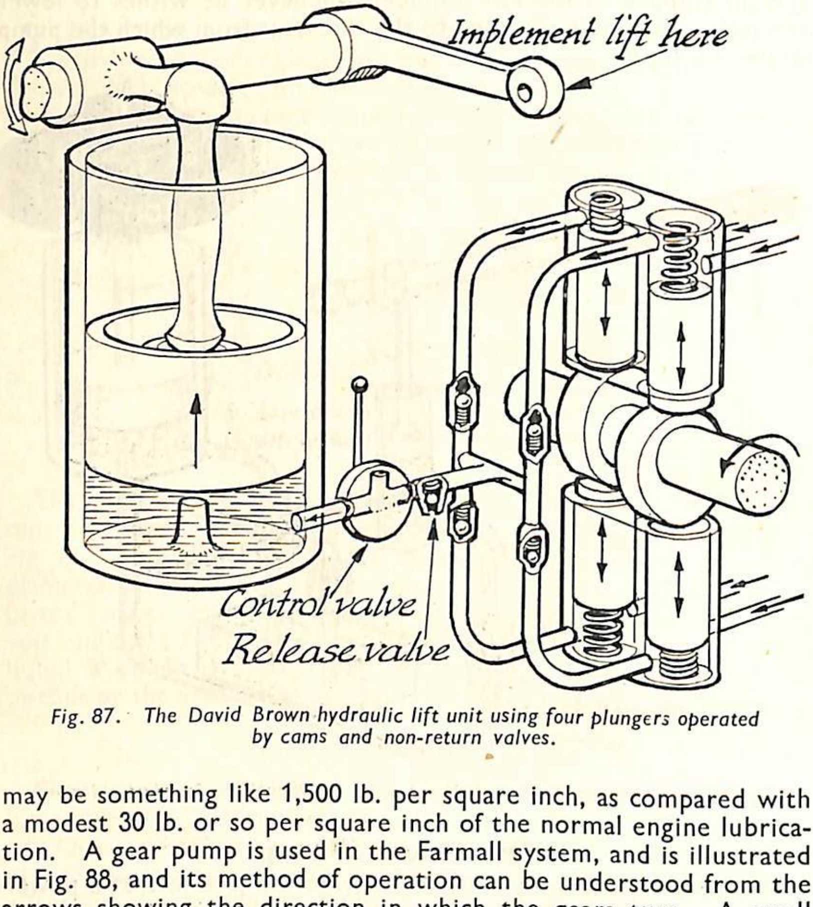


Fig. 87. The David Brown hydraulic lift unit using four plungers operated by cams and non-return valves.

may be something like 1,500 lb. per square inch, as compared with a modest 30 lb. or so per square inch of the normal engine lubrication. A gear pump is used in the Farmall system, and is illustrated in Fig. 88, and its method of operation can be understood from the arrows showing the direction in which the gears turn. A small quantity of oil, carried round in the space between each pair of teeth, is squeezed out when the mating tooth of the other gear begins to enter this space.

These are not the only types of pump in use on tractors, but they will suffice to show two ways of providing the primary requirement of a tractor hydraulic system—a steady supply of oil under pressure. A practical point which will immediately be obvious is that the hydraulic pump, of whatever design, capable of maintaining a pressure of 1,500 lb. per square inch, will be manufactured with very close clearances throughout, so that adequate filtering of the oil is an absolute necessity for trouble-free operation. The smallest amount of grit can cause a great deal of damage.

Methods of Hydraulic Pump Control

The method of control depends, of course, on what the tractor designer sets out to do with the hydraulic system. One of the most comprehensive systems is that used on Farmall tractors, and for this reason it has been selected for detailed description. In its most elaborate form, the system can be used with two toolbars, one mounted under the belly of the tractor and the other at the rear, and enables both sets of tools to start and finish work at the ends of the rows—i.e., there is a delay in lifting or dropping the

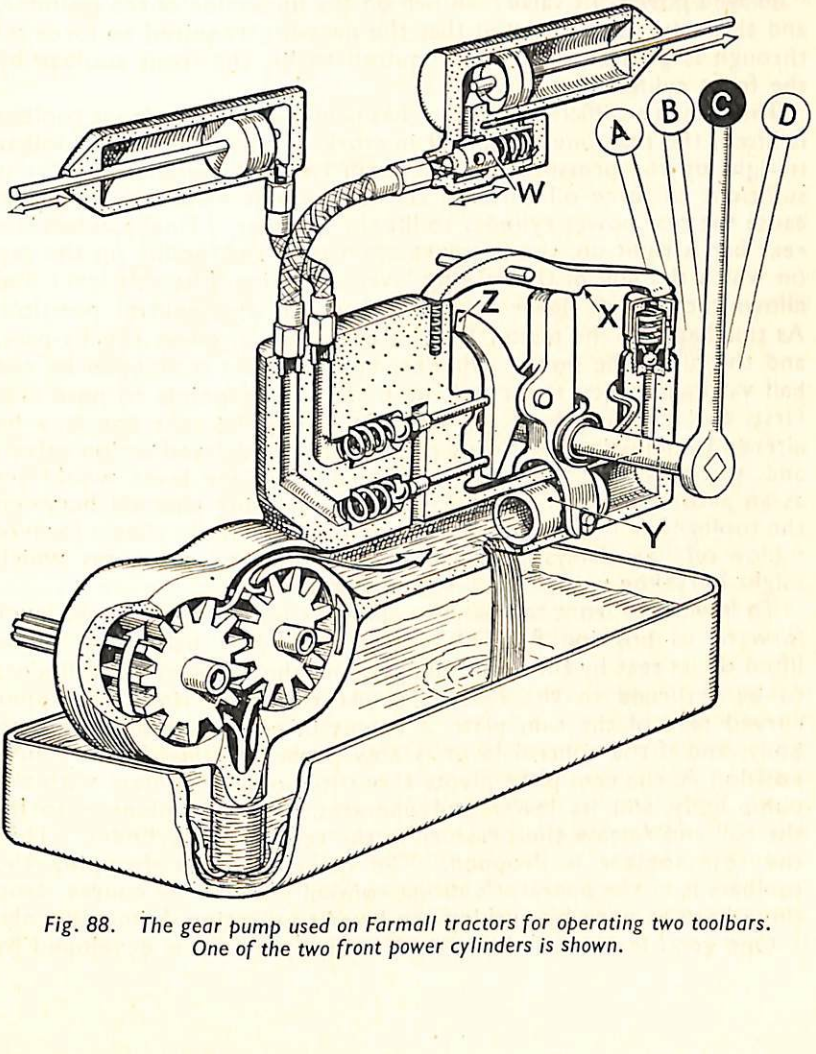


Fig. 88. The gear pump used on Farmall tractors for operating two toolbars. One of the two front power cylinders is shown.

rear bar in relation to the forward one, so that the tractor moves forward the distance between the two bars before the rear one is lifted out or dropped into work.

The operation of this lift may be understood by reference to Fig. 88, in which the control lever is shown in the neutral position. When the lever is so placed the oil from the pump is simply by-passed back to the reservoir, and no pressure is built up. To lift the toolbars, the lever is pulled back to the position D, where it is held by the projection on the underside of the locking lever X. The by-pass is shut off by the piston Y, which slides forward as the control lever is pulled back, and oil pressure immediately begins to build up in the hoses connected to the front and rear power cylinders. The rear cylinder has, however, a spring-loaded valve in the " delayed power-lift valve " shown on the underside of the cylinder, and this valve is so adjusted that the pressure required to force oil through is greater than that required to lift the front toolbar by the front cylinders.

Thus when a sufficient pressure has been built up the front toolbar is lifted, the rear one remaining in work. When the front toolbar is right up the pressure in the system rises still further until it is sufficient to force oil through the delayed-lift valve W, and thus cause the rear power cylinder to lift the rear bar. Finally, when the rear bar is right up, the pressure again rises and, acting on the cap on which the end of the locking lever is resting, lifts this lever and allows the control lever to spring back to the neutral position. As this happens the piston Y slides back and uncovers the by-pass, and the oil in the power cylinders and pipelines is trapped by the ball valves between them and the pump. Two points to note are: First, that the length of the delay in lifting the rear bar may be altered by adjusting the spring pressure in the delayed-action valve ; and, secondly, that the cap which finally lifts the lever would act as an automatic relief if, for example, something jammed between the toolbar and the tractor prevented it being raised. Some form of " blow-off " is always provided to guard against pressures which might burst the unit in some such eventuality.

To lower the front toolbar the operator pushes the control lever forward to position B. This causes the upper ball valve to be lifted off its seat by the small plunger, and the oil from the cylinders to be returned to the reservoir. At the same time the upper curved part of the cam plate Z comes in contact with the pump body, and if the control lever is now pushed farther forward into position A, the cam plate pivots about its point of contact with the pump body, and its lower end operates the lower plunger to lift the ball and release the pressure in the rear power cylinder. Thus the rear toolbar is dropped. The delay between dropping the toolbars is in the operator's direct control ; he can, of course, drop them both at once by pushing the lever to position A immediately.

One good feature of this system is that pressure is developed by the pump only when lifting is actually taking place. At all other times the pump is by-passing the oil at virtually no pressure. Apart from any special features, however, the system is worthy of study as showing the sort of thing that is involved in the working of a tractor hydraulic system intended simply for lifting and lowering implements. The degree of complication of the controls depends entirely on how complicated are the operations to be carried out.

The same broad principles apply equally to some systems in which the oil pressure acts on a piston housed inside the tractor, movement of the piston being used to operate a pair of lifting arms. Systems of this type are used on the David Brown and Fordson Major tractors (see Fig. 89); the piston inside the tractor is equivalent to the ram in the power cylinders on the unit described. It should be noted that, on either of these tractors, a pressure line may be taken if desired to a separate power cylinder.

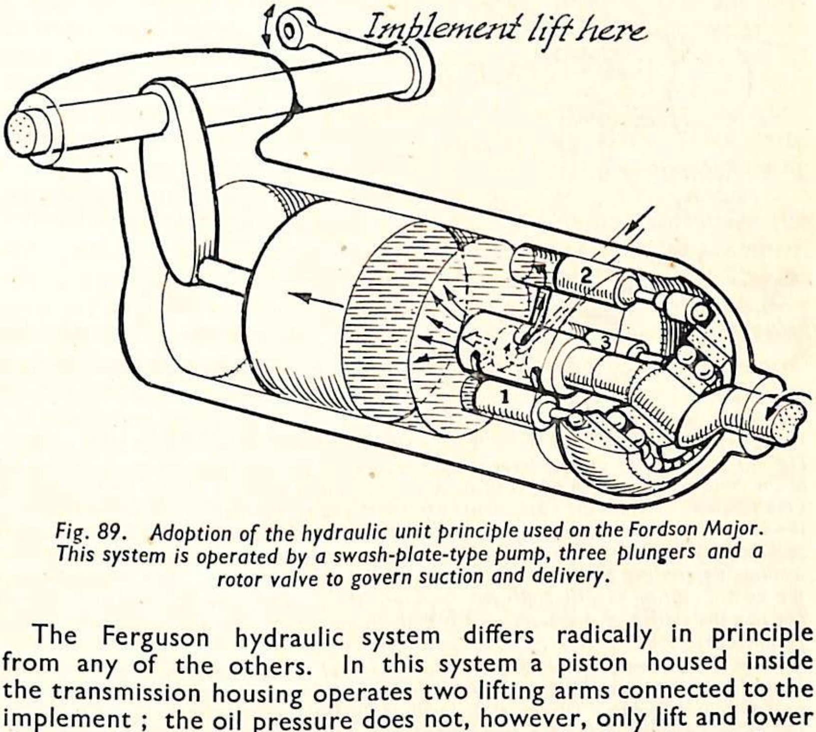
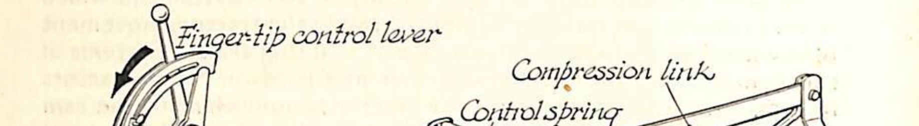


Fig. 89. Adoption of the hydraulic unit principle used on the Fordson Major. This system is operated by a swash-plate-type pump, three plungers and a rotor valve to govern suction and delivery.

The Ferguson hydraulic system differs radically in principle from any of the others. In this system a piston housed inside the transmission housing operates two lifting arms connected to the implement; the oil pressure does not, however, only lift and lower the implement, it actually regulates the depth of working. For a given setting of the hand control lever the hydraulic system maintains a constant draught on the implement. If the draught begins to increase, oil is pumped into the lifting cylinder and the implement is automatically raised a little; if the draught begins to decrease, oil is let out and the implement goes in deeper. This effect is obtained by making the top link operate a spring-loaded control. The advantages and disadvantages of this system as compared with the simple in- or out-of-work type (with which depth of working is maintained by means of a depth wheel) are outside the scope of this handbook.

The operation of the Ferguson hydraulic lift is fully explained in the accompanying diagram (Fig. 90).



EXPLANATORY DIAGRAM OF THE FERGUSON HYDRAULIC LIFT

Fig. 90. When the control lever is pushed forward the cam portion bears on the top of the control fork, which pivots at A—thus the control valve is pulled to the rear or drop position. When the implement enters the ground the top link is pushed against the control spring. Forward movement of the implement compresses the control spring and moves pivot point A forward and thus moves the control valve to a given depth of working determined by the distance forward of the control lever. The compression on the control spring is just sufficient to return the control valve to neutral in which position the weight of the implement is held on the tractor and the implement cannot go any deeper.

If the front wheels enter a depression, the control spring expands, thus allowing the control valve to come slightly out of the pump and the implement to lower sufficiently to maintain its depth. On the other hand, if the front wheels rise on to higher ground, the control spring is further compressed and the control valve lifts the implement slightly in relation to the front wheels.

XXV

ENGINE MAINTENANCE AND REPAIR

HAVING dealt in the previous chapters with various aspects of workshop practice, attention may now be given to actual tractor maintenance and repair.

Many readers are sufficiently skilled to undertake decarbonizing together with the closely related job of valve grinding. There is not much point, therefore, in going deeply into the various questions relating to these jobs, although some remarks on valve grinding may prove useful.

Grinding-in Valves

When a valve is badly pitted considerable and laborious grinding-in may be necessary before all the pits are removed. This difficulty in itself may not be of any great account, but the objection to excessive grinding is that the valve seating becomes worn away so that, in time, and if the grinding be carried to excess, the valve may tend to pocket, thus causing a distinct loss of efficiency in the engine. The proper course to adopt in the case of badly pitted valves is to have the faces trued in a lathe or in one of the special grinding machines designed for this class of work.

In general, the face angle of a poppet valve is 45°, therefore the slide-rest of a lathe should be set over to cut this angle, provided, of course, that the slide swivel is graduated. If it is not, the angle must be set by trial against the valve face, the stem being held in the chuck and, if possible, the head supported on the back centre. Preliminaries of this kind are, of course, unnecessary in special valve-grinding machines.

Before any work is done on a valve make quite certain that the stem is not bent. A ready means of checking this is by using a straight edge, such as a steel ruler, which may be applied to the stem at various points. If held up to the light, or over a sheet of white paper, any fault in this direction will show up clearly.

A bent valve stem may be straightened in the vice by using suitable packing pieces. One packing piece is placed at each end on the concave side, and the third is introduced on the convex side of the bend (see Fig. 91). By carefully regulating the pressure on the packing pieces with the vice handle the stem can be effectively straightened. Go carefully and a little at a time, testing frequently with the straight edge. It is quite a good plan to have a spare set of exhaust valves ready faced, the set being installed in the engine when the head is removed for decarbonizing in place of the worn set, which can be refaced at leisure ready for refitting to the engine next time it is dismantled. In this way only the lightest grinding-in on the seatings is necessary to ensure gas-tightness ; thus the seatings remain in perfect condition.

Whether the valve faces need re-cutting or merely grinding-in, the first process should be thoroughly to clean the valve heads and the stems. One way of doing this if a re-facing tool is not available, is to grip the stem in the chuck of a hand brace and to mount the hand brace in the vice. Whilst the brace is being turned briskly over, a piece of emery cloth soaked in paraffin should be held to the valve. Avoid allowing the emery cloth to round off the valve face, otherwise an unnecessary amount of grinding-in will be called for. The emery cloth used should be well worn, and the paraffin must not be forgotten.

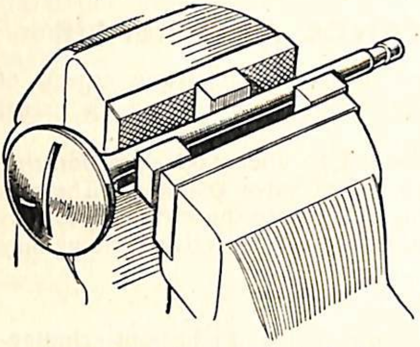


Fig. 91. Straightening a bent valve by means of packing pieces in a vice.

Resurfacing Valve Seats

Sometimes a seating becomes warped or very badly pitted. The cure is to re-cut it with a seating cutter. These tools consist, as a rule, of a toothed cutter, shaped to the correct angle and mounted on a pilot stem which passes down the valve guide. The cutter is rotated by hand or mechanically, according to its type. Hand operation is perfectly satisfactory, as only a very light cut is needed. Accuracy is ensured by the pilot stem, which causes the cutter to rotate true with the valve guide. Where a very high finish is desired an abrasive hone, mechanically driven at high speed, is used instead of a milling cutter.

When seatings are badly worn and the use of valves with oversize heads is impracticable, a satisfactory repair can be made by building up the seating by oxy-acetylene welding. When the new metal has been added the seat is machined to the correct size. Another method is to counterbore the worn seating and to press in a separate seating correctly machined in the form of a ring. This job is best left to the specialist.

Inlet valves or seatings in a normal engine scarcely ever pit to any extent, but it is generally advisable to grind them in lightly with a fine abrasive, followed by the sediment from a metal-polish tin. This ensures a fine finish on both face and seating, and not only makes a gastight joint but ensures that the valves will not subsequently bed down and decrease the tappet clearances.

Dismantling the Engine

When an engine has run for two years the piston rings should be examined. It is common practice to form the cylinder block and crankcase top in one unit ; thus access to the pistons is by removing the sump, uncoupling the big-ends and then drawing down, the connecting-rod and piston assembly.

No difficulty should be experienced in removing the sump of a normal engine, whilst most big-end bolts have castellated nuts and split pins or eared locking washers.

If the engine has been properly erected previously, the big-end nuts will be tight ; a strong and well-fitting box-spanner must be used on them, and for ease in refitting it is advisable to mark the nuts so that they are replaced on the same bolts.

In all probability the big-end caps and the connecting-rods will already be marked for correct reassembly, a letter or a figure being punched in the metal adjacent to the bosses on one side through which the bolts pass. Thus No. 1 con.-rod may be marked A, A or 1, 1, the next B,B or 2,2 and so on. It is essential that the bearings be assembled the right way round.

There will probably be shims fitted between the top and bottom halves of the bearings, and here care must also be taken to see that the shims are retained in their proper positions, because they control the fit of the bearings on the crankpins. If the bearings are to be adjusted, one or more shims—in the case of the laminated type—will have to be removed.

In many cases the white metal of the bearing is contained in bronze shells which, in turn, fit into the connecting-rod. When the big-end bolts are undone the bronze shells will be loose and, therefore, liable to drop out. This must be guarded against, because, in addition to the risk of damage, it is essential that they be correctly replaced, and this cannot be done with certainty unless they are marked.

When the connecting-rods and pistons have been withdrawn and cleaned carefully, inspect the rings, the fit of the gudgeon-pins and the general condition of the pistons themselves. A certain amount of carbon will be found on the underside of the piston crown, and in the bottoms of the ring grooves, and to remove it push out the gudgeon-pin and slip off the rings.

Gudgeon-pins are located in pistons in various ways, but the method of fixing should be quite obvious after a short examination. In modern engines it is usual to allow the gudgeon pins to float in the piston bosses and to limit endwise movement by means of spring circlips sprung into grooves formed in the piston bosses. Another method is to fit pads of either brass or aluminium to the end of the hollow gudgeon-pins, thus preventing their coming into contact with the cylinder walls. In certain cases the gudgeon pins are locked in the small ends of the connecting-rods by means of pinch bolts, and in this case, of course, the pins take their entire bearing in the piston bosses. As in the case of the big-ends, it is essential that the pistons be refitted the right way round on the connecting-rods, so both rods and pistons should be marked before the gudgeon-pins are removed.

Removing Piston Rings

It is not always easy to avoid breaking piston rings when removing them, but the risk can be reduced to a minimum by the exercise of care and the use of proper tools. A simple method of expanding the rings for removal is to take one ring at a time and, having eased it partially from its groove, to slip behind it three strips of tin spaced about 120° apart. This should cause the ring to come quite clear of its groove, and it may then be slipped upwards off the piston. Proprietary tools for ring removal can be bought from most accessory dealers, and they are well worth having. They are adjustable for use on pistons of any size.

If the rings are stuck in their grooves great care will be needed in freeing them ; but it happens frequently that, no matter how careful the operator may be, the ring will break. It is advisable to have a spare set of rings available so that replacements can be made without loss of time.

When the rings are freed from the grooves the carbon can be cleared from the bases of the grooves by means of a narrow screwdriver blade or other suitable tool. The backs of rings will also be coated with carbon, and this should be cleared away. A clearance of only .0015 in., or possibly .002 in., should exist between the sides of the ring and the groove ; a greater amount indicates that wear has been taking place. In this case the groove should be examined carefully to see that the sides are perfectly square and it may be necessary to true each groove by mounting the piston in a lathe. If this is done oversize rings will be necessary, but it is advisable to machine out the grooves to a width for which it is known that new rings can readily be obtained. Better still, get the rings first and then machine the grooves to size.

In addition to being a correct fit in the grooves, the rings must also fit the cylinder bore with only a small amount of clearance between their ends. No really hard-and-fast rule can be laid down, but, as a general guide, it may be said that the gap between the ring ends should be only just sufficient to ensure that the two ends do not touch when they expand with the heat. The following clearances may be taken as quite satisfactory for water-cooled engines : Up to 69 mm. bore, .003 in. ; 70 mm., .004 in. ; 85 mm., .005 in. ; 100 mm., .006 in. ; 110 mm., .007 in. ; 120 mm., .008 in. ; 130 mm., .009 in.

Honing Cylinder Bores

In an old engine the cylinder bores will not be true : in all probability the working part, which is equal, of course, to the stroke of the piston, will be slightly oval, whilst those portions above and below the stroke limits will be truly circular and of the same dimensions as when originally machined, because no wear will have taken place owing to their having, as it were, no work to do.

It is important, therefore, when fitting new rings to make sure that the gap measurement is taken with the ring in the working part of the cylinder ; but, obviously, if the bore is oval the ring cannot touch over its full circumference ; it may, however, bed in to the oval shape of the bore in time, and for this reason the gap should be left as close as possible, as it will increase slightly during the bedding-in process.

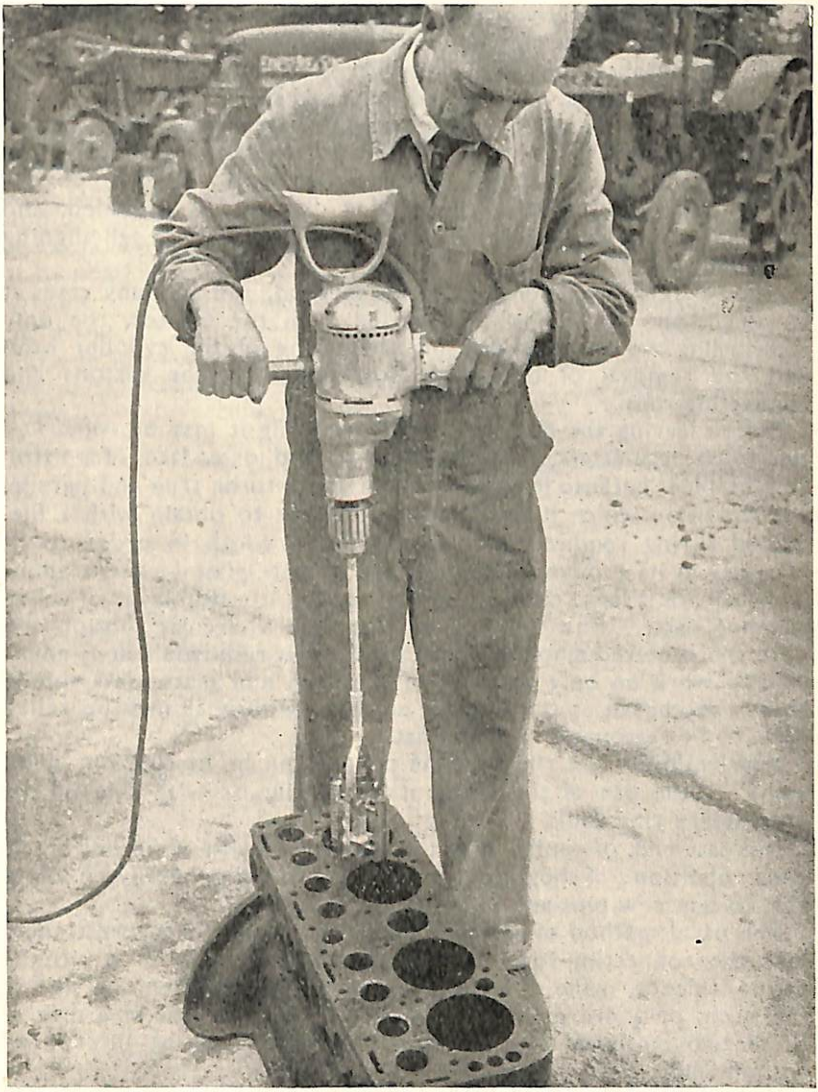


Fig. 92. A useful electric power tool for honing cylinder bores.

When fitting new rings the cylinder bores should be examined at the top ends, as a ridge is frequently to be found at this point. This should be carefully removed by the use of a scraper, otherwise there is the possibility of the new top ring breaking, or at least the engine when run for the first time will emit a disturbing noise as the sharp edges of the top rings come into contact with the ridge in the cylinder.

Until fairly recently worn cylinder bores could be trued only by dismantling the engine and mounting the cylinder block on a grinding machine, the abrasive wheel of which removed the surplus metal necessary to produce an enlarged but truly cylindrical bore.

It is becoming the custom to hone out cylinder bores with a special apparatus consisting of strips of abrasive material mounted on an expanding holder, which can be rotated either by hand or power. Micrometer adjustment of the cutting diameter is provided, and by means of a universal joint in the drive the cutters are self-aligning in the bore.

Good results are obtained by this method, and in many cases it is unnecessary to remove the engine from the tractor, the only dismantling work involved being the lifting of the cylinder head and the removal of the sump, together with the pistons and connecting-rods.

Before leaving the question of piston fitting it may be remarked that in no circumstances should the upper and lower faces of a piston ring be filed, because it is essential for them to be true and parallel—a condition which is practically impossible to obtain with a file. Should a ring require reducing slightly in width in order to fit properly in its groove, obtain a sheet of plate-glass—a piece about 6 ins. square is large enough—and spread on it a thin layer of valve-grinding paste. Rub the ring on this with a circular motion and until the required amount of metal has been removed. It is advisable to work on only one face of the ring, and plate glass should always be chosen as the rubbing surface, because it may be relied upon to be reasonably true and flat.

Reassembly of the rings on the pistons can be carried out quite easily by the use of the three strips of tin, or with one of the proprietary ring tools.

It is assumed, of course, that the pins and small-end bushes are in good condition ; if they require renewing it will generally be found best to buy new pins and bushes.

The usual method of securing small-end bushes is to press them into the connecting-rod. They may be forced out in a vice by fitting a sleeve, made of a short length of tubing, over one side of the bush, or a drawbolt may be used. The reversal of either of these two methods will enable the new bush to be introduced without difficulty.

If the bush is a very tight fit it may be found that the bore will close up slightly, thus making it too tight a fit on the pin. The way to get a perfect fit is by lapping. A lap may consist of a piece of wood turned to such diameter that it will just enter the bush. The lapping medium, fine carborundum and oil, is applied to the lap, which should be revolved in a lathe or by other means, the bush being passed over it and taken from end to end. A properly lapped bush should be perfectly circular and parallel, whilst the finish should be all that could be desired. Thorough washing in paraffin or petrol should follow all grinding or lapping operations. There is no harm in the pin fitting moderately tightly, but it should be possible to rock the piston by hand without any appreciable effort. Take care when fitting a new bush not to forget the oil hole and the oil groove, should one have been provided in the previous bush.

In circumstances where a small-end bush is a slack fit on the pin and no spare is available, it is permissible, in an emergency, to collapse the bush by tinning it heavily on the outside or by knurling it in a lathe, so that when forced back into the connecting-rod the greater external diameter will have the effect of closing up the bore slightly and, therefore, making it a better fit on the gudgeon pin. It must be understood that this is a makeshift method and one which cannot be recommended from an engineering point of view.

XXVI

BLACKSMITHING

TO be able to carry out a certain amount of smithy work is a useful asset to the farm mechanic, for often a small repair job can be done in less time than it takes to get to the nearest smith. The actual tool requirements are not large, for a mechanic can make most of them once he has a forge and an anvil.

The forge should have a gear-driven blower operated by a crank (unless compressed air is available), and the hearth should be at least 18 ins. wide. Good portable forges can sometimes be obtained from Government surplus stocks. The anvil should be of steel and, for preference, weigh from 100 to 125 lb. It should be mounted on a solid block or angle-iron frame at such a height that it can be touched by the knuckles of the clenched fit when standing erect with the arm straight down.

Tongs, hammers (1½ to 2 lb. and 3 to 3½ lb.), chisels and punches are needed, also a metal rule, a square and some calipers.

The important thing when undertaking smithy work is to have a good fire. It must be clean, deep and compact. Ordinary stove or furnace coal will not work satisfactorily in a forge, and the best fuel is blacksmithy coal, which is soft, of good quality and practically free from sulphur. This fuel, when damped and packed down round the fire, forms coke and burns with an intense flame.

Place the iron to be heated in a horizontal position in the fire so that there is burning coke all round it. With regard to the actual work, little can be taught in a book, and the mechanic is advised to experiment for himself on odd scraps of metal before undertaking any work other than bending and straightening, for welding is a task best left to others until proficiency has been achieved. Bending and straightening tool parts forms a large part of smithy work, although drawing tools down preparatory to sharpening and tempering is a fairly frequent job.

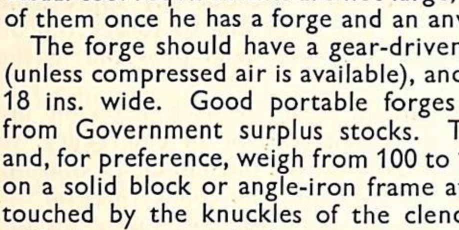


Fig. 93. The iron must be placed in the fire in a horizontal position so that there is burning coke all around it.

One advantage of having a forge is that cold chisels, punches, picks and various implement parts can be re-dressed and tempered. Tool steel may either be purchased from an ironmonger, or it may be recovered from parts of old machines, such as pitchfork tines, axles and drive shafts from old cars, hay-rake teeth and so on. All these oddments should, therefore, be kept, for they will serve a useful purpose one day.

Tool steel can be ruined by wrong treatment: for example, the critical temperature of this metal is about 1,400° F. (or dark red). If heated above this, the grain size is increased and the steel weakened. Hammering the steel when it is dark red will, however, decrease the size of the grain and will therefore improve it.

Heat steel slowly in a good clean fire, and do not get it hotter than the bright red colour or lower than orange. If, however, it is left in the fire a little too long, allow it to cool *slowly* and then re-heat. The term "critical temperature" really is critical, for if the metal is hammered when below 1,300° F. it will probably split or crack, while, as we have already seen, if the temperature is too high (above 1,600° F.) it will be weakened.

Do not hammer too lightly or only the outer part of the metal will be drawn out, leaving the inner part unaffected, so hammer heavily at the bright red stage.

After the tool has been forged it should be annealed, or softened, before it is tempered. This evens up the strains caused by alternate heating and hammering, and it is done by heating it once more to a dark red and allowing it to cool slowly—preferably out of draughts.

Tool steel that is heated and then cooled rapidly becomes hard—much too hard for use as a tool—and it has to be tempered. In any case, the steel should be made hard before tempering. The amount of softening depends upon the temperature to which the steel is heated, and for practical purposes in the farm workshop temperatures are judged by the colour of the metal.

Suppose, for example, a cold chisel has been forged. Heat it to a dark red for a distance of about 3 ins. from the cutting end, and then plunge about 1½ ins. of the point into cold water, moving it up and down slightly until the end is cool enough to hold in the hand. Then polish one side of the blade with emery-cloth, an old file, or a piece of brick, and watch the colours come down to the polished part. The heat contained in the body of the tool slowly spreads along towards the point, and the first colour to be seen will be yellow, followed by straw, brown, purple, dark blue, and finally light blue. When the dark blue reaches the actual cutting edge, dip the end quickly in water and move it about to cool thoroughly. Do not drop the whole chisel in the water, as this will harden the shank, and the tool will break when used. When all redness has left the shank, drop the tool right into the water and leave it until quite cool, when it will be ready for grinding.

A centre-punch is made a little harder than a cold chisel, and a screwdriver a little softer. Not all steels have the same degree of hardness when cooled at a given colour, so it may be necessary to experiment a little in order to get the exact temper needed for the work to be done.

XXVII
PIPEWORK

THERE are few farms in which pipes of some kind are not used, and the mechanic is sooner or later bound to be called upon to fit up some water-piping. The tools needed are not many, the chief being a Stillson or other similar wrench, a pipe-cutter, dies and a good bench vice.

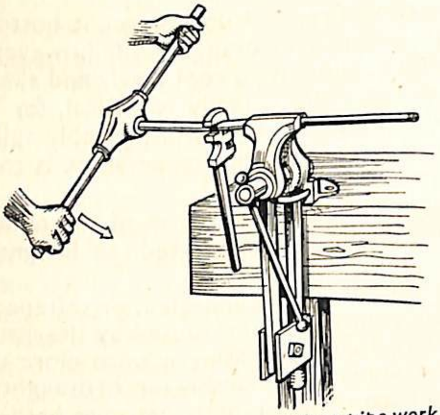


Fig. 94. Using a Stillson wrench on pipe work when a proper pipe vice is not available.

Pipe wrenches, of which one is illustrated in Fig. 94, are obtainable in several sizes, but a 14-in. and an 18-in. will cover most of the work. A proper pipe vice (see Fig. 95) is preferable, although useful work can be done with the usual workshop type, some assistance being given by the use of the pipe wrench, as shown in Fig. 94.

Unless a considerable amount of pipe-work is to be done—such as when fitting up an irrigation scheme, or piping a farmhouse for water, stocks and dies can be hired from a builders' merchant. The same applies to a pipe-cutter, although the smaller sizes of tool—$\frac{1}{8}$ in. and $\frac{1}{4}$ in.—are useful for a variety of jobs on machinery and on engines.

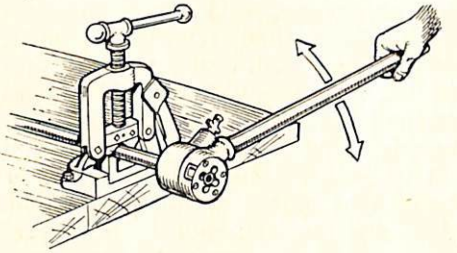


Fig. 95. This pipe vice is the correct tool to use.

Piping used on farms is generally galvanized iron, as it is less liable to rust. The fittings, too, may also be galvanized, although cast or wrought-iron are frequently used.

Unlike bolts, pipes are measured according to their *inside* diameter, although it will be found that the actual internal diameter is a little larger than the nominal. Pipes are made in sizes ranging from $\frac{1}{8}$ to $\frac{1}{2}$ in. by steps of an eighth of an inch, and up to $1\frac{1}{4}$ ins. by steps of a quarter-inch. Fittings are designated by the size of pipe they will fit, and not according to their own diameters. For instance, a $\frac{1}{2}$-in. elbow has an inside diameter of about $\frac{3}{4}$ in., because it has to screw over the outside of a pipe which has an *inside* diameter of $\frac{1}{2}$ in.

To save time and trouble when ordering pipe fittings, Fig. 96 shows the common types and their names.

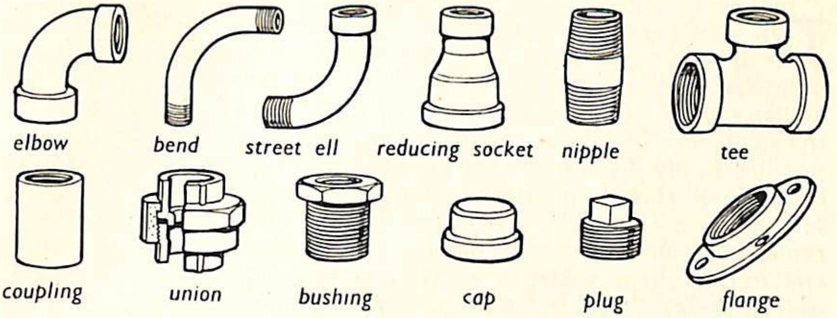


Fig. 96. Some common types of pipe fittings.

Whenever one has to tackle a piping job of any size, it is as well to take careful measurements and to plan out the whole system, including the type of fittings required at each bend or join. If, as is often the case, one has to take the pipes away to be threaded, check all measurements carefully before cutting.

Pipes can, of course, be cut with a hacksaw, and a fine-tooth blade (24 teeth per inch) is usually the best. A pipe-cutting tool comprises a steel frame and three steel disc cutters, one fixed on the head and the other two movable along a slide.

Place the tool on the pipe so that the cutting disc covers the line to which the pipe is to be cut, turn the handle to grip the pipe between the cutters, and then turn the tool round the pipe, tightening the cutters a little each time round to force the cutters into the pipe. A little oil should be used.

Cutting tools leave a burr inside the pipe, and this should be removed with a pipe reamer or with a half-round file. If the burr is left, the obstruction will decrease the carrying capacity of the pipe.

When cutting threads, use a firm pressure to start the dies working, but afterwards the tool will feed itself in. Remember that pipe threads are not parallel like those on a bolt, but are tapered, so if the die is screwed on so that more than one thread projects through the die the tool will cut a parallel thread. Lubricate the die well during cutting.

When erecting pipelines, always coat the threads with a jointing compound or with a mixture of graphite and a heavy grease. A paste of Portland cement and linseed oil can also be used. If the piping is to be used for drinking water, apply the jointing material to the threads on the pipe and not on the fitting, otherwise some of the compound will be left in the pipe and contaminate the water.

XXVIII

FARM WATER SUPPLY

THE existence of a satisfactory piped water supply, good in quality and adequate in quantity, is recognized as a prime necessity in most branches of farming. All farms need water for human consumption ; farms carrying stock need drinking water in the fields and buildings. Dairy farms need water for washing and sterilizing, and there is an ever-growing use of water for crop irrigation. In all these applications a supply of water piped to the point of utilization can effect a saving of labour which in many cases is remarkable and alone may justify the installation costs of such a system. In many respects a mains water supply has advantages over other methods, but a private system often falls little short of this and may prove less costly.

Sources of Water

In any projected scheme it is obvious that the quantity of water required must be closely estimated and the potential source examined to make sure that it is adequate. Even more important, where drinking water and dairy washing water are concerned, is the bacteriological quality. Preliminary tests should be made if possible before work is started, and where surface or soil water contribute to the supply routine examination should be continued at regular intervals. The hardness of the water supply is of interest in so far as water heating or steam production is concerned. Deposition of scale or sludge on the heating surfaces of steam boilers and similar equipment may be severe with hard water, leading to added costs of maintenance and loss of efficiency. Very soft water, particularly in peaty districts, may be corrosive.

Sources of water may be classified in two groups—those which occur at ground level, such as rivers or streams, lakes or ponds and springs ; and those which occur underground. The latter may be tapped by a well shaft : if the water level is less or more than about 25 ft. from the surface the well is termed shallow or deep respectively. In practically all cases wells are fed by underground springs. An underground source of water may, however, be at a great depth, in which case it may be tapped by a borehole. Borings may be made several hundred feet deep, and are lined with steel tubes. When the boring penetrates the water-bearing stratum it may be found that the underground pressure forces the water to the surface : in this case it is termed an " artesian " well. If the water rises only part-way it is said to be " sub-artesian."

Sometimes the water source occurs at a level above the point of utilization. In such cases it is usually possible to build a collecting tank at the source, from which water may be conveyed by gravitation, thus eliminating the need for any pumping equipment. The running costs of such a system are thus virtually negligible.

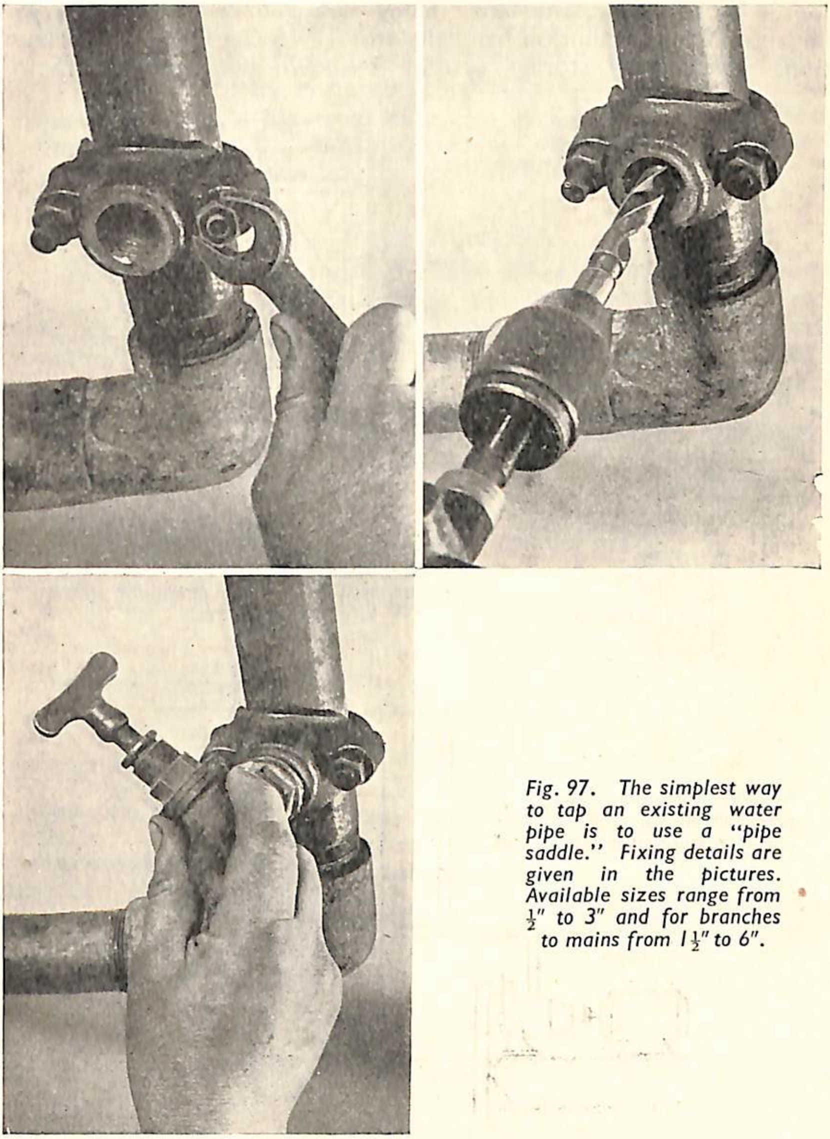


Fig. 97. The simplest way to tap an existing water pipe is to use a "pipe saddle." Fixing details are given in the pictures. Available sizes range from ½" to 3" and for branches to mains from 1½" to 6".

The Mechanics of Water Supply

Most water supply problems involve pumping water from a source to a storage, the latter being arranged to provide energy for automatic distribution from the storage to the points of utilization. The gravity storage system is shown diagrammatically in Fig. 98. The vertical height of the pump above the water source is termed the *suction head* ; this is limited to 20-28 ft. according to the type of pump. The vertical height of the storage tank above the pump is termed the *delivery head.* These values added together

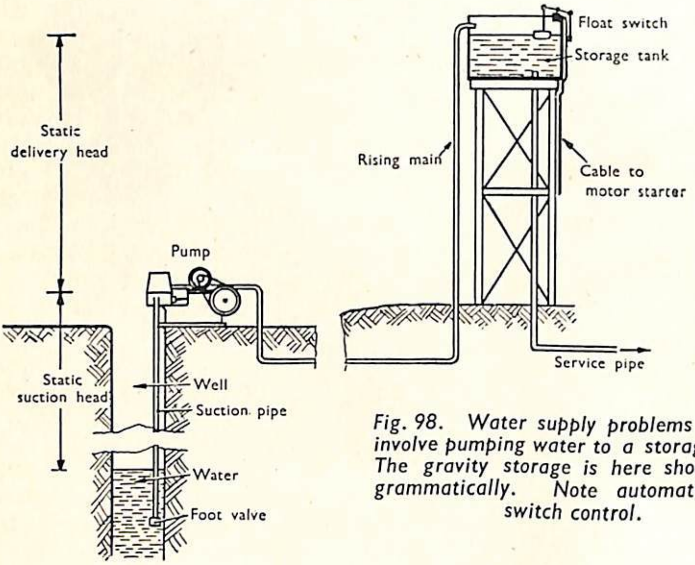


Fig. 98. Water supply problems usually involve pumping water to a storage tank. The gravity storage is here shown diagrammatically. Note automatic float switch control.

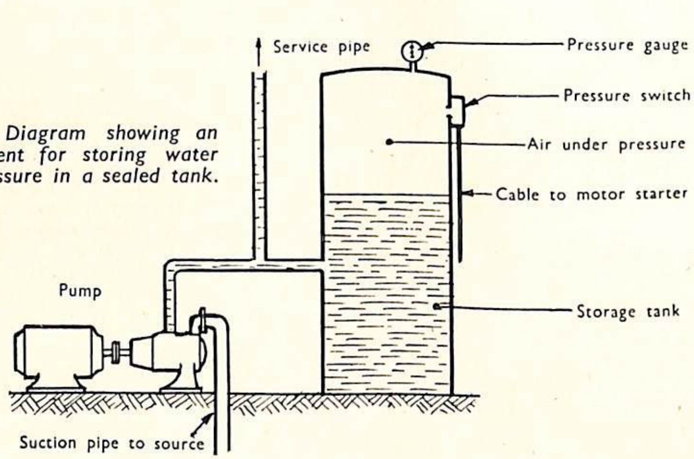


Fig. 99. Diagram showing an arrangement for storing water under pressure in a sealed tank.

give the *total static head*, and this is usually expressed in feet. The storage tank must be above all the service points.

Fig. 99 illustrates the pressure storage system, and the suction head is determined as before. The storage tank may be at the same level as the pump, but being sealed it can store water under pressure. The equivalent delivery head in this case can be expressed in feet by multiplying the pressure in lb./sq. in. by 2.3. If the tank is above or below the pump, the calculated delivery head in feet must be increased or decreased by the vertical difference in level.

Pipe Friction

When water flows through a pipe it has to overcome frictional resistance. This absorbs energy, and in consequence represents an added load when pumping water and a decrease of potential energy in distribution. It is convenient to express pipe friction in the terms of head, that is an equivalent extra vertical height. The total, or manometric, head which the pump must overcome can therefore be expressed as follows :—

For the gravity system—

$$H=h_s+h_d+h_f$$

where H=total head (feet)
h_s=suction head (feet)
h_d=delivery head (feet)
h_f=total friction head (feet)

For the pressure system—

$$H=h_s+h_d+2.3\,p+h_f$$

where H=total head (feet)
h_s=suction head (feet)
h_d=gravity delivery head (feet)
p=storage pressure (lb./sq. in.)
h_f=total friction head (feet)

Note.—In the above equations h_s would be negative if the source is above the pump ; similarly h_d would be negative if the pump is above the storage tank.

Calculation of Friction Head

Friction head is estimated in practice by referring to tables or graphs, an example of which is given in Fig. 100. It is proportional to the length of the pipe, and therefore the values are given per 100-ft. run. For a given size of pipe the friction head is proportional to the square of the pumping rate—i.e., if the pumping rate is doubled, the friction *increases* four times. For a given pumping rate the friction head is inversely proportional to the fifth power of the pipe size—i.e., if the pipe size is doubled the friction *decreases* 32 times. The curves in Fig. 100 give the friction head per 100-ft. of straight pipe at various pumping rates for several common sizes of galvanized water pipe. An additional allowance must be made for the friction loss at pipe fittings such as bends or elbows. Four such fittings may be considered equivalent to an additional 100-ft. length of pipe.

The total manometric head calculated as above and expressed in feet is used to select a suitable type of pump and to determine the power which will be required. This is expressed by :—

$$\text{Horsepower} = \frac{H \times 10\,Q}{33{,}000}$$

where H=total manometric head
Q=pumping rate in gal./min.

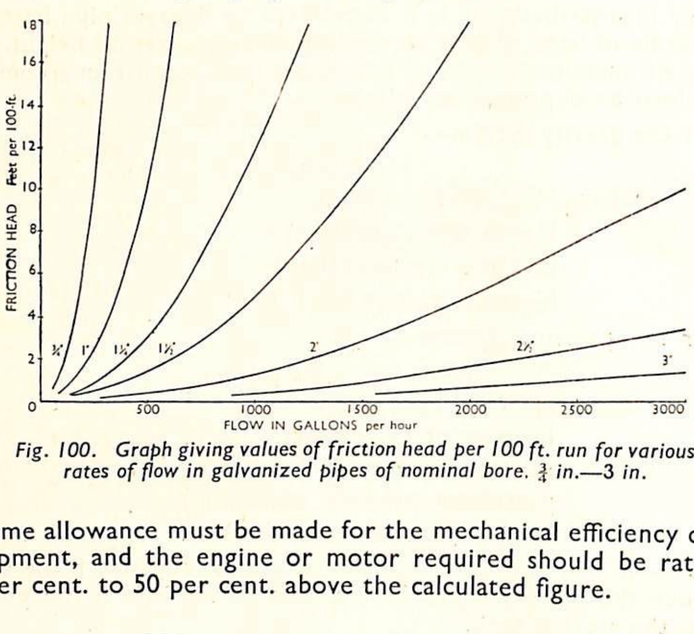


Fig. 100. Graph giving values of friction head per 100 ft. run for various rates of flow in galvanized pipes of nominal bore. ¾ in.—3 in.

Some allowance must be made for the mechanical efficiency of the equipment, and the engine or motor required should be rated at 33 per cent. to 50 per cent. above the calculated figure.

Water Supply Equipment

There are now many forms of power-operated pumps which are suitable for water supply, and only their leading characteristics can be mentioned here. It should be appreciated that all pumps are devices which create a low pressure at the inlet or suction, and a high pressure at the outlet. The water source is normally at atmospheric pressure, and this forces water up to the pump. The maximum height between the pump and the source is therefore the head, which is equivalent to normal atmospheric pressure, that is, 2.3×14.7, or about 34 ft. Friction and other factors diminish in practice to a maximum of about 28 ft. Not all types of pumps can create a low pressure when not full of water ; those which can are termed "self-priming." Those which cannot must either be primed with water for starting or submerged below water level so that the suction head is nil or negative.

Centrifugal Pumps

This type of pump is often used for pumping at high flow rates against comparatively small heads. Having no valves, it can be used for such purposes as irrigation or drainage, where the water to be pumped contains grit or other suspended matter. An impeller is rotated inside a circular casing at the centre of which is the water inlet. As the impeller is rotated the water is forced outwards by centrifugal action, thus creating a high pressure at the periphery of the casing and a low pressure at the centre. The delivery is taken tangentially from a volute chamber. This type of pump is not self-priming, and often is arranged to operate flooded or immersed. A multistage vertical type is illustrated in Fig. 101. In this a number of small centrifugal pump units are mounted together, each unit delivering to the unit above, thus building up the delivery pressure in stages. An additional feature of this type is that an electric motor of special design is incorporated, the complete assembly working under water.

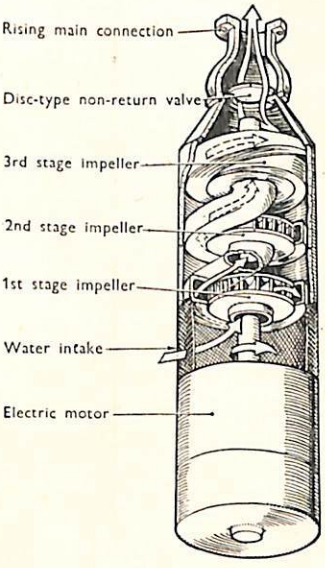


Fig. 101. Explanatory illustration of centrifugal pump capable of working submerged.

Rotary Pumps

There are many forms of rotary pumps operating on either the positive displacement or the turbine principle. Most of them can be used for water-supply purposes, but they often are designed for special purposes, and in consequence are not always competitive in price for water pumping.

Reciprocating Plunger Pumps

This type of pump, operating on a positive displacement principle, exists in several forms. A commonly-used type is a horizontally-opposed double-acting pump capable of operating on a 25-ft. suction head. A 2 h.p. engine would give an output of 500 gal./hr. against a total head of 150 ft. The horizontal steel plunger is reciprocated in the two opposed cylinders at the ends of which are brass ball valves to control the suction and delivery. An air vessel is fitted above the delivery branch to lessen the pulsating effect of each delivery stroke.

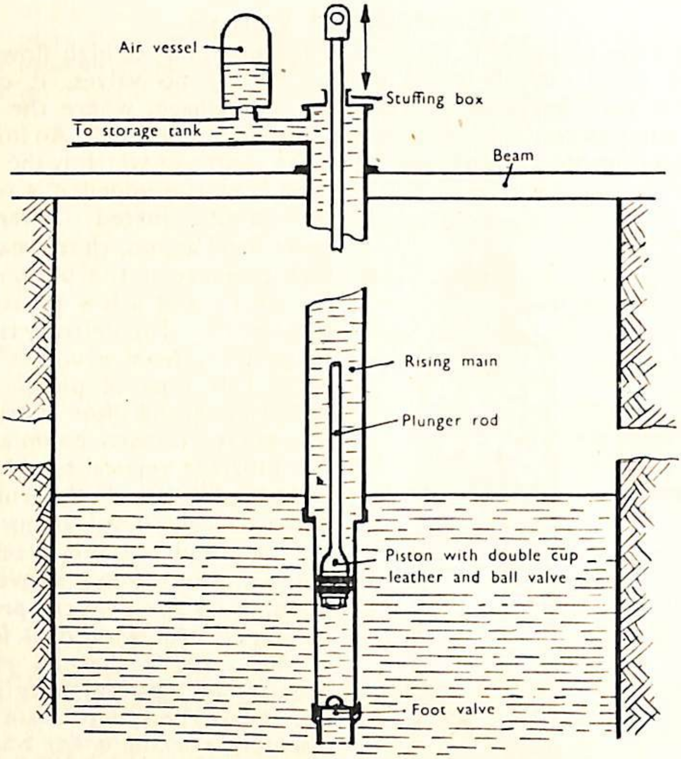


Fig. 102. Diagram of pump suitable for a deep well.

In another form this type of pump can be used for deep wells. The well-head gear is arranged above a large-diameter rising main, which extends down the well or borehole to below the water level. The plunger rod is inside the rising main, and is reciprocated by the gear above, while at its lower end is a piston working inside the cylinder attached to the bottom end of the rising main. The latter is long enough to ensure that the cylinder is always under water and is large enough to allow the plunger rod and piston to be withdrawn for servicing without disturbing the cylinder or rising main. A diagram of the equipment is shown in Fig. 102 and an illustration of a well-head gear is shown in Fig. 103.

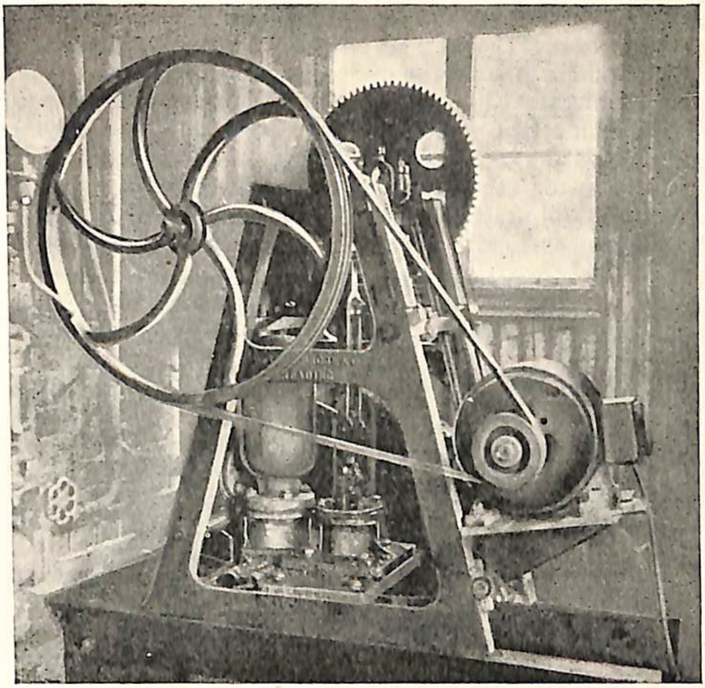


Fig. 103. The head gear of a deep well pump. The plunger rod passing through a gland into the top of the rising main can be seen under the frame : the air vessel and delivery pipe is to the left of this.

Hydraulic Rams

The hydraulic ram is a water engine and pump combined, and is illustrated diagrammatically in Fig. 104. Water flows through a large-diameter drive pipe "A" into the chamber " B " escaping through the valve " C." The pressure on this valve causes it to close, and the inertia of the water in the drive pipe then produces a pulse of high

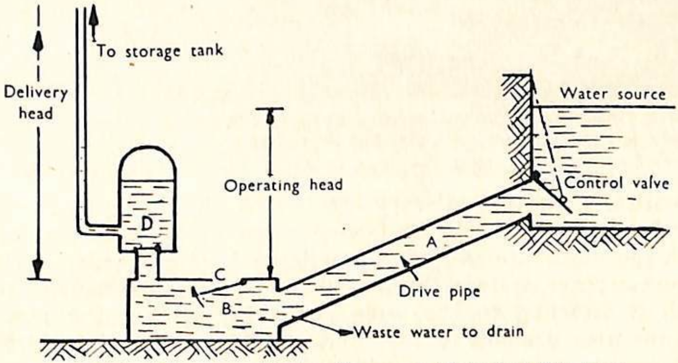


Fig. 104. Diagram of hydraulic ram, explained on this page.

pressure in the chamber. A small quantity of water is forced through the delivery valve " D " as a result ; this relieves the pressure, and valve " C " opens to start the cycle of operations again. The water pumped is only a small proportion of the water used, and thus an ample supply must be available. For example, if the driving head were 10 ft. and the delivery head 100 ft., then theoretically 10 per cent. of the water used would be pumped to storage and 90 per cent. wasted. In practice these figures would be 5–7 per cent. and 93–95 per cent. respectively.

Methods of Control

Where a pump is driven by an internal-combustion engine, manual control is usually necessary. An electric motor can, however, be automatically controlled very easily. With the gravity storage system a float switch can be incorporated in the tank and used to switch the motor on and off at any desired water levels. With the pressure-storage system, illustrated in Fig. 105, a pressure-operated switch is attached to the tank, and this switches the motor on when the pressure falls to, say, 20 lb./sq. in. and switches it off when the pressure reaches, say, 40 lb./sq. in.

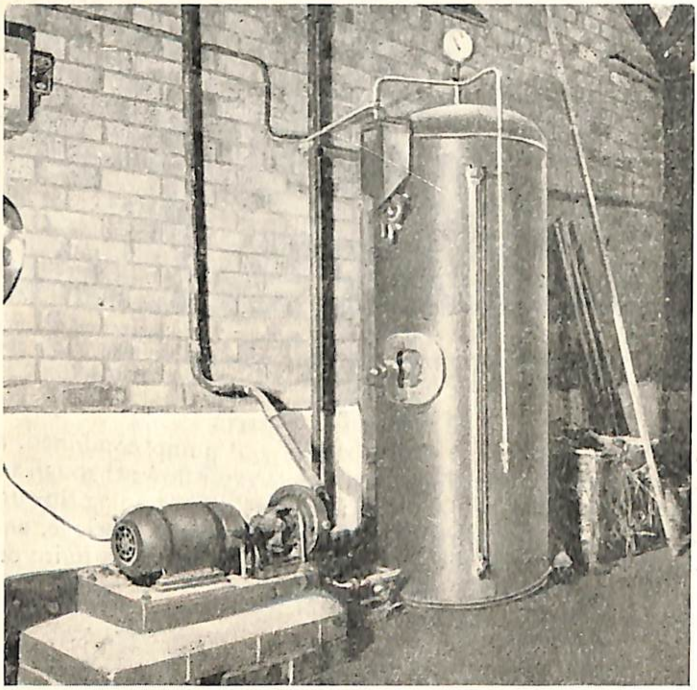


Fig. 105. A pressure-storage used as a booster. The centrifugal pump is fed from an overhead tank and pumps water into the pressure-storage tank. The pressure-operated switch at the top of the tank automatically controls the pump motor.

XXIX

OVERHAULING A FARM WATER PUMP

(The Argosy)

IT is odd to reflect that the more reliable a machine the greater the abuse and neglect it has to suffer, and no better example of this paradox is seen than in the farm water pump. These appliances are installed, set to work and then usually forgotten. That they go on working day after day for months on end without any attention whatever is a real tribute to the manufacturer. All the same there is bound to come a time when a failure occurs, and at this moment there are many who wish they had not forgotten to service these appliances which are so badly needed at this time.

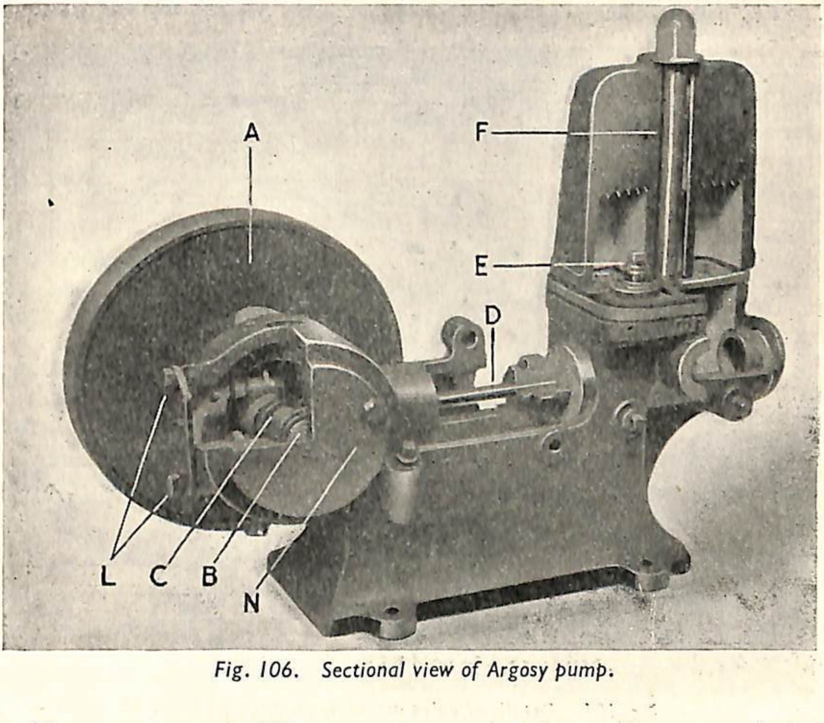


Fig. 106. Sectional view of Argosy pump.

There are many different makes and designs of pump, and the Argosy is a typical example of such units. This machine is made in two models, a single cylinder and a twin ; but as both are identical in operation, we have selected the single ram plant as being the easier to photograph and to describe. The pump can be driven by an electric motor or a petrol engine, or by belt from shafting, but we will confine our article to the pump itself. This consists of a crankshaft, connecting-rod and piston on much the same lines as those in a petrol engine although much smaller. Screwed into the top of the piston, however, is a length of rod carrying on its outer end two leather bucket washers, which operate in a further cylinder so that the piston merely acts as a crosshead.

Fig. 106 is a general view of a sectioned Argosy pump, and it shows the flywheel A, the crankshaft B, the big end C, the plunger D (screwed into the crosshead which is not seen in this illustration), the valves E, and the air chamber over them.

Dismantling

To overhaul the pump begin by removing the air chamber. This is secured by a long bolt F. Unscrew this bolt and lift the air chamber off, when the valve plate G, in Fig. 107, will be revealed. This plate has a rubber washer above and below it, these being shown at H in Fig. 107. Lift off the valve plate with valves.

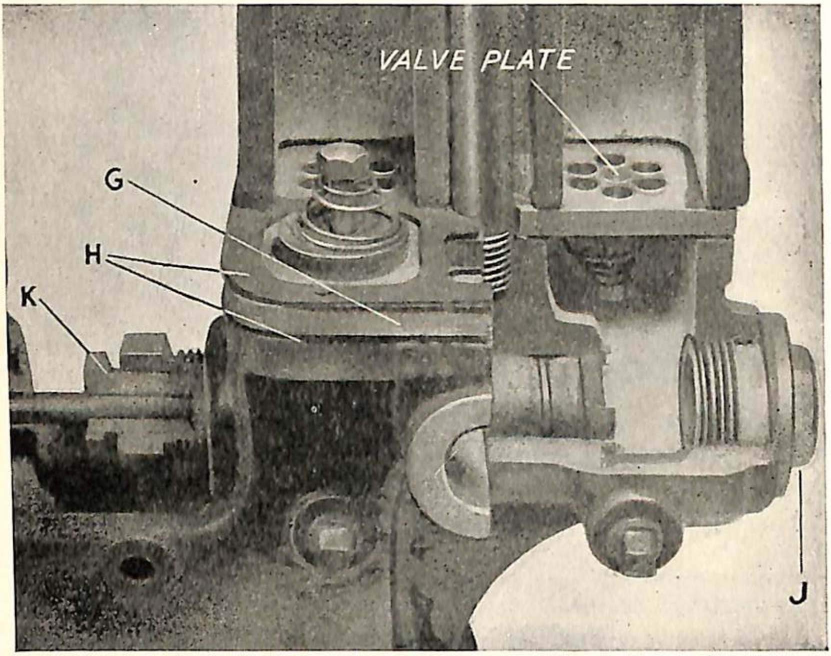


Fig. 107. Details of valve assembly on Argosy pump.

At the end of the machine is a cap J, behind which is a fibre washer. Unscrew this cap (left-hand thread), and then slacken back the gland nut K. Turn the flywheel until the plunger is right forward, and then with a box spanner inserted in the hole of the end cap J, unscrew the plunger rod from the crosshead and pull it out. Reference to the illustration will show that this rod has two bucket washers on it, both facing different ways. On pumps designed for cold water, leather is used, but if for hot water there is a gunmetal piston instead.

The crankshaft is removed by first slackening the belt tension screw (this is not shown in the photographs as the machine was not fitted with a motor) and remove the belt. Next take off the plate at the end of the crankcase by removing the two setscrews L (Fig. 106). Turn the flywheel round until the big-end of the connecting-rod is nearest the aperture, and then take off the big-end cap. Push the connecting-rod away from you clear of the crankshaft.

Take out the flywheel securing screw and then remove the flywheel by placing a block of wood on its inner edge and tapping it with a hammer. Do not hit the flywheel with the hammer or it may break, being of cast iron. Move the block round and round the circumference of the wheel and tap until the wheel is free. On the opposite side of the machine is a cover seen at N in Fig. 106. Take out the three screws and remove the cover, when the crankshaft and its cap can be knocked out together. The crankshaft has two ball races attached to it, but unless these need renewing they should not be disturbed, but merely washed clean in paraffin and then lubricated. There is a fibre washer seal between the end plate and the crankcase. See that this is not damaged.

The crosshead, connecting-rod and big-end bearing are of gunmetal, and should the bearing need to be taken up, hold the cap in a vice and file a little off the face which meets the connecting-rod. Take off only a little at a time, and remove all the burrs before fitting. If the bearing does not make good all-over contact with the shaft journal, scrape it a little with an engineer's scraper. The crosshead is attached to the connecting-rod by a gudgeon pin, which is parallel and a push fit. Should this wear, a new pin will usually take up slackness, but if it does not, fit a new connecting-rod. Make sure that the oil groove on the top of the connecting-rod is clear and that the hole carrying the lubricant to the gudgeon pin is not obstructed.

The valve plate is a stout bronze casting drilled as shown in Fig. 107. The four valves are alike, but two are on one side and two on the other. Each consists of a rubber disc (gunmetal disc on the hot-water pump), a valve guard, guide and a spring. All the springs should be of equal strength, so compare them with one another and replace those which are weak. Clean the plate and valves carefully before replacing them. Both sides of the valve plate are alike, so it does not matter on which side the valves come so long as they are placed opposite as shown, the two outlets being on the top when re-assembling. If gunmetal valves are fitted it is as well to mark each one before removal as it is better that they are returned to their original places in case the seat is worn.

The gland is important. It consists of a stuffing-box, which screws into the pump body casing, a gland nut and, between them, the packing. This packing is a three-spiral strip of special material, and it should be inserted in the stuffing-box carefully and then compressed with the gland nut. Glands should never be too tight, for although their object is to act as a water seal, a certain amount of water should be permitted to seep through to lubricate the ram. The spiral packing can be replaced at any time without taking out the rod.

After assembling the machine carefully, pour oil into the crankcase filler until it will hold no more. It is likely that the pump will need priming after overhaul, so leave the fitting of the valve plate and air chamber until the end, then pour some water into the valve chamber, fit the plate and air chamber, secure them, and then start up. The gland nut can be adjusted after the machine has run for a few minutes. Remember that the suction pipe must be absolutely free from air leaks or the pump will not work properly.

XXX

BELT TRANSMISSIONS

BELTING can be a useful, trouble-free and safe means of transmission; it can also be time-wasting and even dangerous. Trouble starts from the common belief that a belt drive is an old fashioned appliance which requires no care or attention, but once it is realized that a belt is really an intricate piece of mechanism it will be treated with the respect it deserves.

Highest efficiency in belt transmission is obtained by using a belt that is as inelastic as possible, and for agricultural purposes the balata belt is to be recommended. Canvas belts not treated with balata gum or with rubber are affected by moisture, and should be used only for occasional indoor work. Leather belts are favoured by many, but they are more expensive and susceptible to wet or to damp conditions. They are not so strong as the woven cotton belt, as the following table shows :—

	Tensile strength per sq. in.
Leather (oak-tanned)	3,000 – 4,000
Leather (mineral tanned)	4,000 – 7,000
Solid woven cotton	8,000 –12,000
Rubber-frictioned	6,000 – 8,000
Balata	6,500 – 9,000

Textile belts, when worn smooth, can be restored by an occasional dressing of castor oil, and this oil should also be applied if the pulley is polished brightly, indicating some slip. But a belt will not slip if it is tensioned correctly, and the application of powdered resin or other so-called restorers invariably creates belt strain by imposing a temporary but heavy overload. Oil is particularly harmful to balata and cotton belts, as it tends to separate the plies.

When fitting a new belt ascertain the length of the drive by passing a steel tape or a piece of strong cord round the pulleys. Cut the belt to a length 1 per cent. less than that of the drive. In many cases the right length of belt can be ordered and made up as an endless belt. After a few days' running the belt will stretch, and unless the distance between the pulleys can be altered, cut out $\frac{1}{2}$ per cent. of the belt length. If the belt is a long one, its own weight adds materially to the tension, so the above percentages can be halved in such cases. As to thickness, the general rule is to run not more than 1 mm. of thickness for every inch of pulley diameter.

The following formula is useful in calculating belt lengths :—

Let R be the radius of the larger pulley, and r the radius of the smaller pulley, d the distance between their centres, and let $S = R - r$ for a *straight* belt, and $S = R + r$ for a *crossed* belt.

Then, if S is small compared with d, the length of belt is given by :—

$$2d+\frac{22}{7}(R+r)+\frac{S^2}{d}$$

If S is not small compared with d, the formula becomes more complicated, and it is better to use a tape measure, unless you like mathematics. The above formula does not take into account the 1 per cent. deducted when cutting the belt.

Belt Drive Faults

Belt Slip

This can be caused by the belt's being too slack, too smooth, or moist from water or oil. Remedies for these have already been given, but if the belt still slips, it is possible that the power is too great for the belt, and a wider or thicker belt should be used.

A flapping or surging belt is either badly made, poorly fastened, too light for the load, or too long and in need of a jockey pulley. Unevenly faced pulleys or pulleys which do not run true are also causes of surging. Pulleys should not be flat but slightly convex on the face, particularly for high-speed work. This construction helps to keep the belt on the pulley by centrifugal force. On the other hand, if the pulley is given too much crown, there will be poor contact between it and the belt. A correct crown measures 3/32 in. at the centre for every foot of pulley width.

Uneven Travel

This can also be traced to faulty pulleys, but is more likely to be due to badly fitting fasteners.

Falling Off

This is the final result of continued belt slip or to overload. Misaligned pulleys will reject a belt as fast as it is replaced.

Breakage

A worn-out belt, especially of the size used for threshing, constitutes a real danger to workers, and should be replaced before breakage occurs. Pressing on a belt with a fork handle and throwing dirt or cavings on to pulleys in order to make a belt grip mean only one thing—the destruction of the belt. If a belt fractures behind the joint, it indicates too large a fastener for the pulley.

Fastening Belts

The nature of a balata belt makes it specially suited to metal fasteners, of which there are three main types. The simplest is the flexible steel " Alligator," but when fitting it, the angle of the teeth should not be altered. Fasteners with projections are dangerous and also unnecessary. Drives with jockey pulleys or guide pulleys are best served with hinged fasteners.

Wherever possible, the simplest forms of drive should be employed because the addition of guide pulleys and flanges increases belt wear. Figs. 108 and 109 are the best drives.

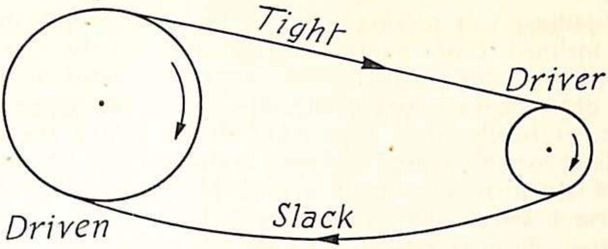


Fig. 108.

Note that with slack section of belt as in Fig. 109, an arc of greater contact is obtained than as in Fig. 108.

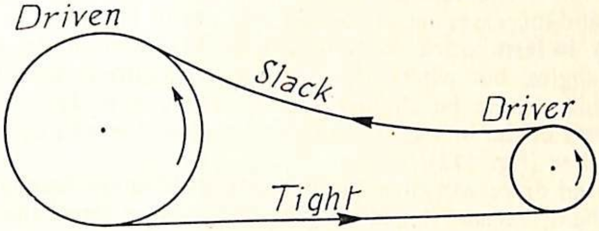


Fig. 109.

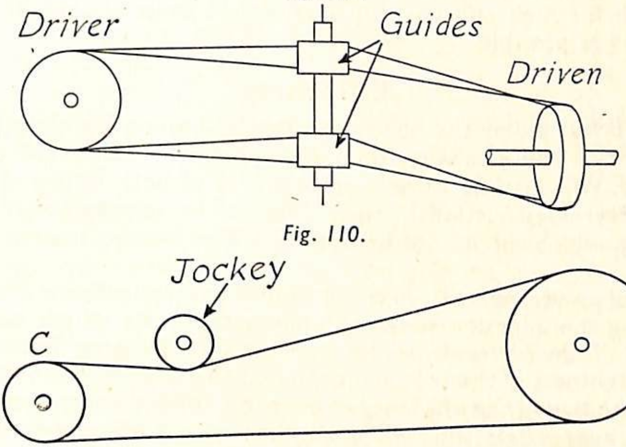


Fig. 110.

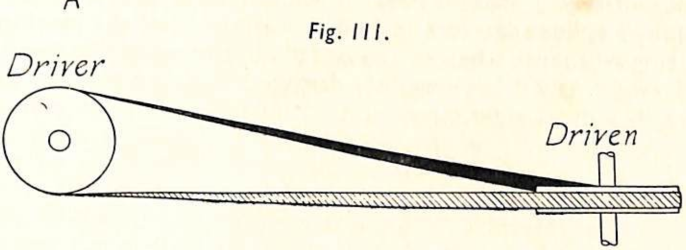


Fig. 111.

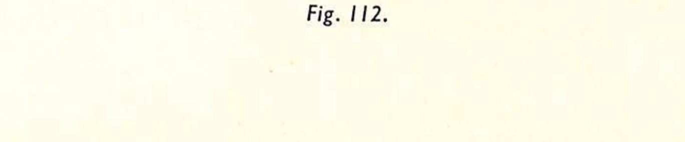


Fig. 112.

Guide pulleys and jockeys have to be used where the shafts' axes are inclined to one another, as sometimes is the case where a pulley on a threshing engine drives the straw elevator or where the latter is driven by a portable engine. Guides are often awkward to adjust, especially when engine and driver pulley are on rough ground, and for this reason a strong argument can be advanced in favour of elevators with built-in engines, allowing for a simple, open drive between the pulleys.

Increased efficiency can be obtained by a flat-faced tension, or jockey, pulley when a large pulley is used to drive a small one close to it and the arc of contact is thereby too small to give efficient transmission. The tension pulley is mounted on the slack side of the belt and increases arc of contact ABC, as in Fig. 111. It is seldom necessary in farm work to have a drive between shafts with axles at right angles, but where this arrangement cannot be altered the driver pulley must be aligned with the driven pulley so that the middle part of the belt as it leaves one pulley is in the central plane of the other (Fig. 112).

A crossed drive will turn the driven pulley in the opposite direction to the driver and imposes a greater strain on a belt than an open drive. Thick, narrow belts are the best for running crossed, although for high efficiency in open drives belts should be as thin and wide as possible.

Efficiency

On a *driver* pulley the belt is constantly slipping from a tense into a slack state and vice versa on a *driven* pulley. This " creep," as it is called, will in time cause a smoothness of both belt and pulleys which decreases frictional grip. This can be counteracted by belt dressing, which should not be used liberally, for the reasons already given.

Loss of power, apart from creep, is due to various forms of friction, including the adhesion between pulleys and belts which cannot be avoided if the drive is to function at all. Bearing friction, due to the tightness of the belt, has been decreased by modern engineering methods, and the efficiency of properly applied and adjusted belts is very high. Belt slip, while another source of power wastage, is not entirely a disadvantage if viewed as a safety valve. For example, a sudden increase in load or a jamming of the machinery it is driving will cause a belt to slip or fall off, thus stopping mechanism which might have been seriously damaged if forced to keep moving longer by a more rigid means of transmission.

XXXI

COMPRESSED AIR ON FARMS

THE use of compressed air is growing in many industries, for it is an extremely flexible means of power and one which, moreover, can be stored. Its value for crop and fruit-tree spraying is well known, and when one realizes how great are the uses of compressed air, there will be many more plants used on farms. Below are a few jobs which can be done with air, together with the number of cubic feet required for each :—

	Cubic ft. per min.
Radiator testing	1
Tyre inflation	1.5
Spark plug cleaning and testing	1.5
Valve grinding	2
High-pressure lubrication	2
Welding and brazing	4
Engine cleaning	4
Vacuum cleaning	4
Spring spraying (for motor vehicles)	4.5
Spray painting	4– 7
Vehicle washing	5
Riveting	10–12
Tin-plate shearing	10–12
Hammering	10–12
Tool grinding	10–12

In addition to these, an air compressor can be used for protecting machinery with anti-rust solutions, for drying magnetos, for blowing dust from machinery, for operating a forge and so on. Air may be used also for spraying buildings with limewash, and the spray gun for paint will keep machinery from the ravages of weather, besides decorating the interior and exterior of the farmhouse.

An air compressor is a simple machine comprising many of the features of a petrol engine. It has a cylinder, piston connecting-rod, crankshaft, valves, etc., and it requires little attention beyond regular lubrication. Air is drawn into the cylinder as the piston descends and compressed as the piston rises. The degree of compression, however, depends upon the pressure it has to overcome, for both of the valves are of the automatic type, being held lightly on to their seatings by springs and having no other operating mechanism, such as pushrods and cams.

When the piston descends in the cylinder it creates a partial vacuum, and as the outer air is at a higher pressure, the inlet valve opens and the cylinder is filled. On the rise of the piston, the air is compressed and lifts the discharge valve from its seating, but if the compressor is connected to a storage tank or to a tyre, the pressure in the cylinder has to rise above that in the tank before the discharge valve will open. Thus when starting from scratch the pressure is very small, but increases as it encounters resistance.

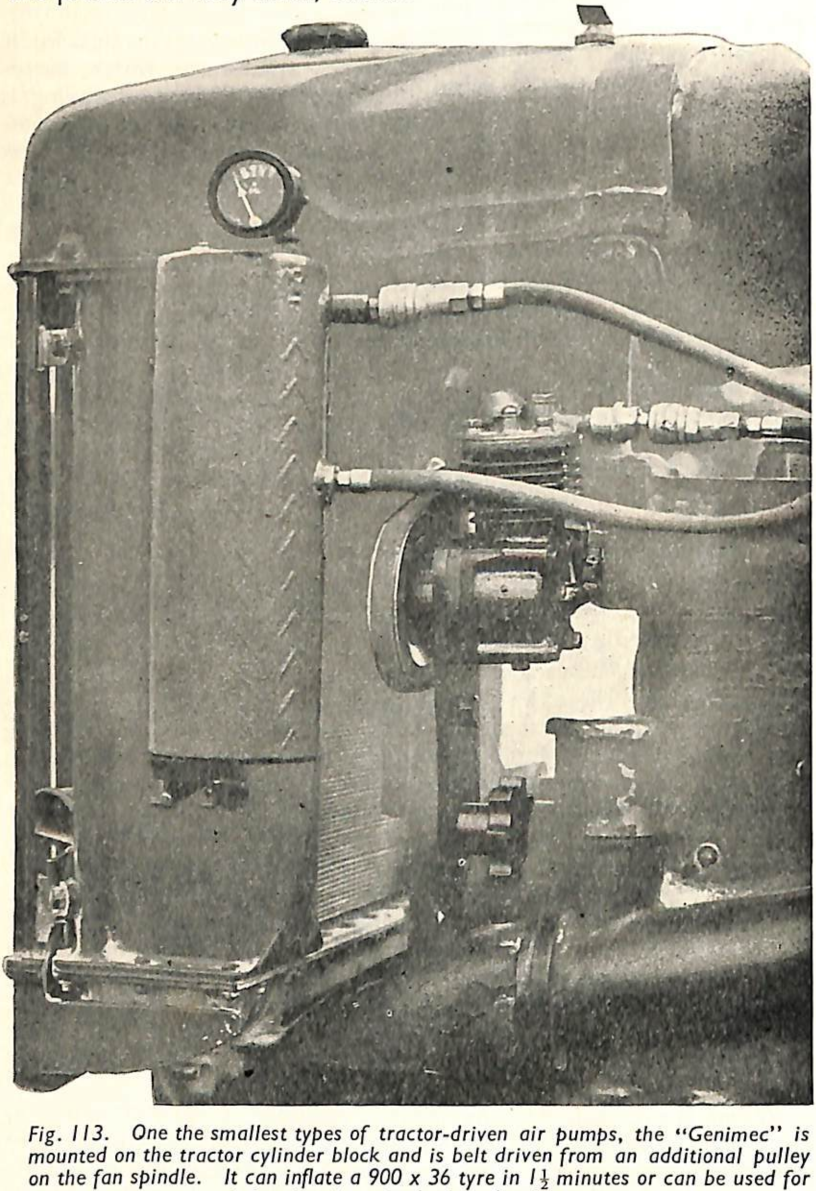


Fig. 113. One the smallest types of tractor-driven air pumps, the "Genimec" is mounted on the tractor cylinder block and is belt driven from an additional pulley on the fan spindle. It can inflate a 900 x 36 tyre in $1\frac{1}{2}$ minutes or can be used for paint spraying, spark-plug cleaning, etc.

As was seen in the chapter on Diesel engines, air that is compressed becomes hot—the temperature rising with the degree of compression—so the compressor cylinder has to be cooled, either with water or by an air draught such as is found in many industrial-type petrol engines, although ducting is not generally used.

All compressors have an air filter, which should be periodically cleaned. The filters are simple affairs, consisting usually of a wire-mesh container packed with a loosely woven fabric which may be washed in water when dirty. Petrol or paraffin should never be used as serious trouble may result if the filter is in any way damp from either liquid.

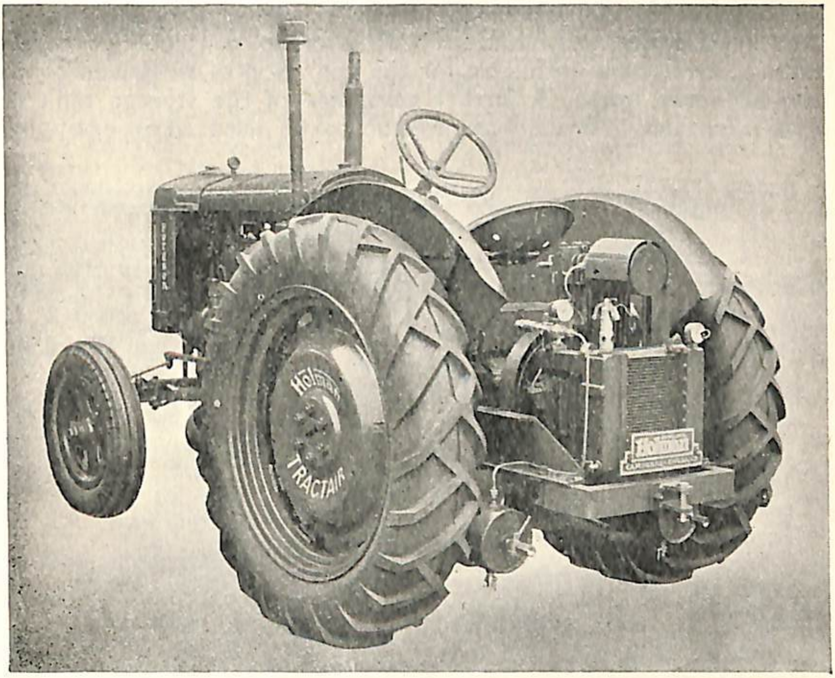


Fig. 114. Another tractor-mounted compressor this "Tractair" two-stage machine is driven from the tractor p.t.o. At a normal working pressure of 80 lb. per sq. in., the output is 70 cubic ft. per min.

A certain amount of oil always finds its way past the piston rings into the compressor cylinder, and the heat of compression results in the formation of carbon just as in any internal-combustion engine, but to a much lesser degree. It is therefore necessary at intervals—say 12 months—to remove this deposit from both the cylinder head and the piston crown and to clean and reface the valves.

Compressors are made in a wide variety of sizes, and some have two or more cylinders. In most of these it will be noticed that one cylinder is considerably larger than the other, and this denotes two-stage compression. The air is first compressed in the larger cylinder and then transferred to the smaller one which compresses it still further. But the majority of the compressors needed for farm work are of the single-stage type, requiring one cylinder only. Those for larger outputs may have two cylinders, but this is merely to give smoother running.

Storage tanks are used to provide a supply of air which can be drawn upon when the compressor is not running. They also serve to cool the air, and are used as a means of damping the impulses of air from the compressor itself. If no storage tank were used the air would come to the various appliances in the form of a series of strong pulsations, and, although this is of no consequence when inflating tyres, it is unsuitable for the operation of air-driven tools and for spray work. A further advantage of the storage tank is that it enables a smaller compressor to be used. For example, a spray gun takes from 4–7 cubic ft. of air per min., and a brazing hearth 4 ft. It would not be necessary to have a compressor with an output of 11 cubic ft. per min., nor even 8, because it would

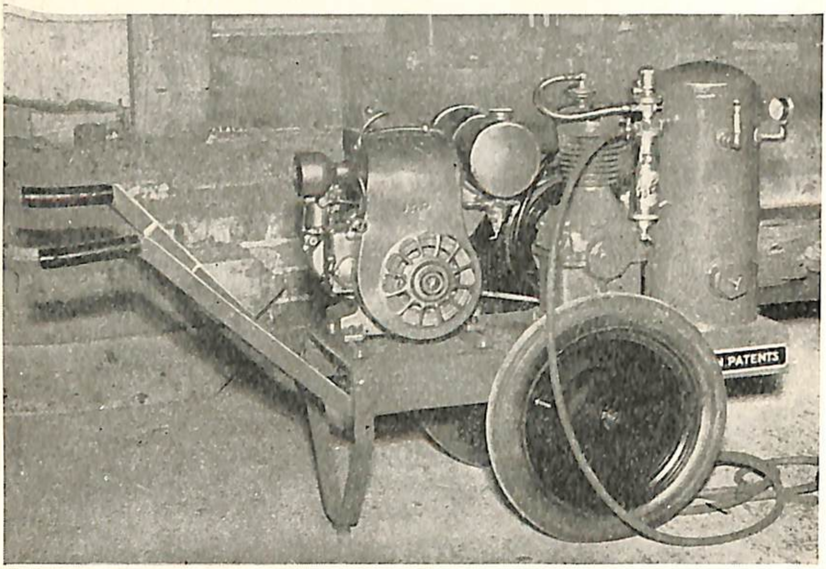


Fig. 115. The most useful type of compressor for average farm use. This B.E.N. 'P5' model is portable, powered by its own 1 h.p. petrol engine and, with an output of 5 cubic ft. per min. at a working pressure of 10-60 lb. per sq. in., capable of paint spraying, tyre inflation and the operation of small pneumatic workshop tools.

be seldom that both appliances are in use at the same time. A compressor delivering 4 cubic ft. would be sufficiently large to operate a spray gun, because in practice this is never on fully all the time the compressor is running. Assuming that the gun uses 7 ft., a 4-ft. compressor and an air receiver would be suitable for all general purposes.

Because the air which leaves the compressor contains a small but definite amount of oil, the air receiver must be fitted with a drain cock and drained at intervals. Condensation, too, takes place and both oil and water will eventually reduce the capacity of the receiver. But the chief reason for fitting a drain tap is that compressed air and oil forms a highly explosive mixture. More than one garage proprietor has had his storage tank explode through neglect to drain it regularly.

Air compressors should always be firmly fixed to a solid base, and if the installation is for permanent use in a building, see that the plant is placed close to a wall so that the air intake pipe is kept as short as possible. If, however, a long intake cannot be avoided, the pipe should be increased in size to allow for the resistance of the air flow. An air filter must be used, and it is best at the intake pipe end rather than between the pipe and the compressor, as this saves the trouble of dismantling the air line to clean the filter. Protect the filter from the weather by erecting a hood over it.

The delivery pipe from the compressor to the storage tank should slope slightly towards the tank to prevent moisture draining back to the compressor. Air lines leading from the tank to various points around the building should also slope towards the tank, particularly if air-operated tools are used.

Not all appliances and services need the same pressure of air, and in any case a storage tank is usually " inflated " to a much higher pressure than that generally used so that a pressure-reducing valve is practically a necessity in most installations. If, for example, the storage tank contained air at 100 lb. pressure, and the full blast were turned into a forge, it would blow the fire all over the building. A reducing valve is simply a needle-type valve similar to that on many carburetter main jets. The air passes through the valve into a small cylinder that is fitted with a pressure gauge so that the exact pressure required is obtained.

Beyond keeping the compressor lubricated and the storage tank drained at intervals, a compressor needs very little attention. After a time, however, carbon will form on the piston head, inside the cylinder head, and round the valves, but its removal is a simple matter. Valves are more delicate than those on an internal-combustion engine, and need careful handling. They seldom need grinding in, and when they do this is usually confined to the application of a very fine abrasive such as metal polish. The main thing to watch when replacing compressor valves is to see that every part is perfectly clean and that the valve springs are correctly positioned.

XXXII

ELECTRICITY ON THE FARM

Mains Supply

ELECTRICITY has been long in coming to the farmer, and whether supplied from outside sources or generated on the farm, it means that the farm mechanic will be called upon to service such things as motors, generators, lighting installations and so on. In view of the fact that electricity is a subject with which few country folk are acquainted, a general explanation of it will prove of value. If the information at the beginning of this chapter appears to be elementary to some readers, it is hoped that they will appreciate that others come to the subject with no previous knowledge.

When an electric battery torch is switched on, current flows from the battery through " conductors " which may consist of a metal strip, the metal case of the torch, or a piece of wire. The current passes through the bulb and back to the battery, and unless there is this complete circle or " circuit," there will be no light. In a mains supply, large generators at a power station some miles away take the place of the battery.

Now electricity is a force which can be driven along conductors in much the same way as water is pumped through a pipe. In its passage through the conductor, the electricity meets with some resistance, and if this is great and the pressure of electricity sufficient, the conductor becomes heated. In an electric fire, for example, the wire coil offers a fair amount of resistance, and so we get the red glow and the heat. The filament in an electric light bulb offers much more resistance, and it reaches the white heat of incandescence, so providing the illumination required.

In all house-lighting circuits, and indeed in all mains electrical circuits, a device called a fuse is fitted, and its object is to prevent the wiring from overheating to such an extent that the insulation burns off and there is a danger of fire. A fuse is simply a piece of wire which has a low melting-point, so if anything occurs to heat up the wiring system, the fuse melts long before the danger-point is reached. As the fuse carries the current, this ceases to flow when the metal melts.

The words " pressure " and " current " have been used, and reference has been made to water pressure. In some houses, the pressure of the water at the kitchen tap may depend on one of two things ; it may be due to gravity, or to the power of the pumps at the water company's pumphouse. In either case the pressure is measurable in pounds per square inch, but electrical pressure is measured by " voltage." One volt is the unit of electrical pressure, and sometimes it is called the " potential difference."

When water is pumped through a pipe, the quantity which flows is generally reckoned in gallons—which means the number of gallons which flow in one minute. The term used by electricians to denote quantity is the " Ampere." One can have a high pressure of electricity, but the amount which flows may be low. In a magneto, for example, the pressure of the current which jumps across the sparking-plug gap may be 10,000 volts or more, but the amount, or amperage, is extremely small. That is why such a current will not harm anyone, although it gives them a shock. On the other hand, a current with a voltage of 230 but an amperage of less than half might be sufficient to cause death. It is, therefore, not the voltage which causes the damage, but the amount of resistance offered by the body. The term used to denote resistance is called " Ohm," and the resistance offered by a human body might be as much as 50,000 ohms. Now if a person with that amount of resistance has an electrical current at 500 volts pressure put through him, he would certainly feel it, although it might not harm him. But if his hands were wet this resistance would be considerably lowered (because water is a good conductor of electricity), so that the bodily resistance might drop to 5,000 ohms. This would mean that the actual quantity (i.e., amperage) of current would be one-tenth, and this might well prove serious. It is always wise to play for safety and to switch off mains current before attempting to effect a repair.

Just as a tank or a pipe will withstand so much pressure before it bursts, so will electrical machinery. If a lamp designed for a pressure of 110 volts is put into a 230-volt circuit, the filament gets more pressure than it can properly withstand, and either the filament melts immediately or the lamp will give a brilliant light for perhaps a few minutes (or at the most a couple of hours) and then break. On the other hand, if a 230-volt lamp is put into a 110-volt circuit, the filament will not attain its full brilliance and the light will be poor. Of course, the filament would last indefinitely in these circumstances. The same principle operates when an electric motor is put on the wrong voltage, for either the coils of wire will overheat and " burn out "—this meaning that the insulation will char and the coil be rendered useless—or the motor will turn slowly but be incapable of doing the work for which it was designed.

Before going into the question of maintenance work, something must be said about the supply. The current from a battery always flows in one direction, and is known as direct current (D.C.). Many generators, too, are D.C., but the public supply is, almost without exception, alternating current, or A.C. House lights, electric fires and many small motors operate equally well on either current, but it is necessary to explain here the difference between these two types of current, because many appliances will run on one but not on the other.

An alternating current is one which reverses its direction and passes along the conductor first in one way and then in the other, this change usually taking place 50 times every second. Under the National Grid system there are comparatively few power stations, but each has an enormous output. This is cheaper than having a larger number of smaller stations.

When it is desired to convey electrical energy over a long distance one of the problems involved is that of reducing to the minimum the waste and loss during transmission. Large quantities of direct current need thick copper cables, and these are expensive to buy and costly to install. Small wires, on the other hand, result in considerable loss due to their resistance and the dissipation of the heat thus generated. Owing to the demand for current, the alternating current supply system was used for this requires but thin wire.

Current is generated at the power station and "stepped-up" to a very high voltage—132,000—but is of no use to the farmer or to the townsman, so by means of transformers it is reduced to 400 volts. With alternating current, lighting is generally at a pressure of 230 volts, and the larger type of motors at 400 volts. This current is generated as "three-phase A.C. at 50 cycles per second," and at an initial voltage of 11,000. This, as we have already seen, is stepped up to 132,000 volts for transmission purposes. Alternating current may, however, be sent out as "single-phase" as well as three-phase, and in single-phase there is but one wave of current, but in three-phase three separate surges are sent out one after another, and all in the same direction. Under this arrangement a wiring system is provided giving 230 volts when two lines are connected, and 400 volts when another line is used.

Generating Electricity on the Farm

There are several methods by which electricity may be generated on the farm, and the type of plant selected depends partly upon local conditions, partly upon the amount of electrical power required, and sometimes upon the amount of money available. Of the plants which can be used we have: (1) An internal-combustion engine (petrol, paraffin or Diesel) coupled to a dynamo, which charges storage batteries; (2) an automatic set (again either petrol or Diesel), in which pressing any of the lighting or power switches starts up the engine and switching off the last lamp shuts down the plant; and (3) a wind-driven dynamo which charges batteries as in No. 1; and (4) hydraulically operated dynamo, which can either provide direct light and power or can charge batteries. No. 2 has only the batteries needed for starting purposes.

The first type of installation is common enough, and the maintenance of engines and dynamos has already been dealt with elsewhere in this book. The batteries, however, deserve special mention, for although they are simple enough in themselves, they do need regular attention. Whatever type, batteries consist of one or more cells, each of which is capable of holding approximately 2 volts pressure of electricity. The number of cells coupled together depends upon the ultimate voltage required, for a 6-volt battery has three cells, and for 110 volts 55 cells are needed.

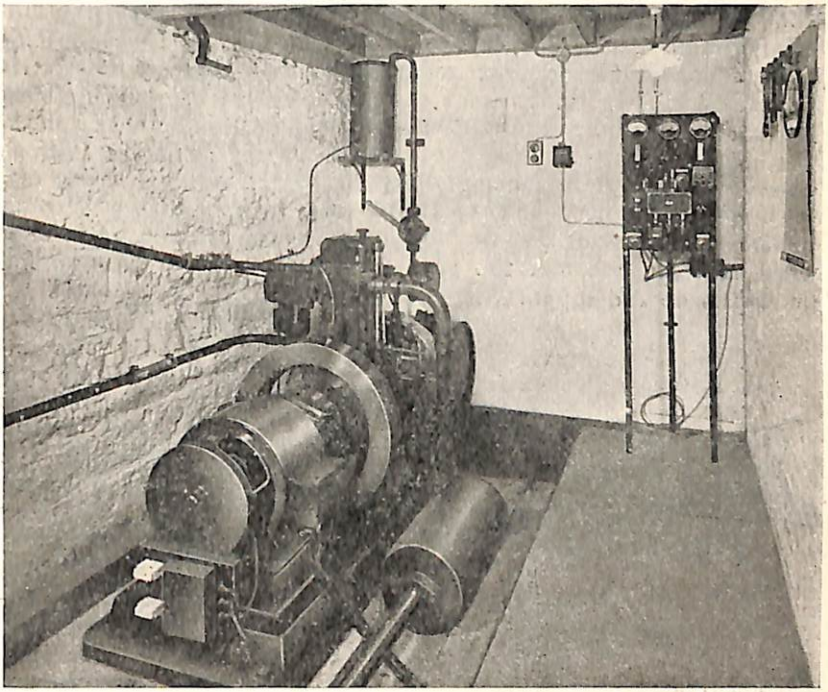


Fig. 116. Lister Diesel engine generating plant.

Each cell consists of an acid-proof container, in which is an electrolyte (a solution of sulphuric acid and distilled water) and one or more pairs of lead plates. There is no need to discuss here the chemical change which takes place when a battery is charged or is discharging, but the net result of a charge is that each cell contains 2 volts pressure of electrical energy. The quantity of energy, however, depends upon the surface area of the lead plates, and that is why engine-starter batteries have several sets of plates, for they combine to give a good deal of current for turning over an engine.

Battery care simply consists of keeping the electrolyte level just above the top of the plates, and this is done by adding distilled water only. Rain water may be used so long as it is clean and has not been collected in an iron tank. The battery terminals, too, need attention, for they should be protected from corrosion by smearing them with vaseline.

Several manufacturers market automatic plants, and where an electrical supply is needed for household use, such machines are useful because one does not have to start the engine up every time a light is needed. These plants have only one small battery that is used for starting, for the current for light and power is drawn direct from the dynamo. Maintenance is simple as far as the engine and the dynamo is concerned, but a really sound knowledge of electricity is needed to adjust the electrical switch gearing in the event of its failure. Because automatic plants are self-starting, they must either run on petrol or be fitted with Diesel engines. The latter is, of course, cheaper to operate, but it is rather costly to buy. Both types are available in models which have a capacity of from 800 watts (a little under a unit) to 10 kilowatts or more, and by using special switch gearing two or more plants can be linked up so that when the load becomes too great for a single plant, the second one starts up and supports it.

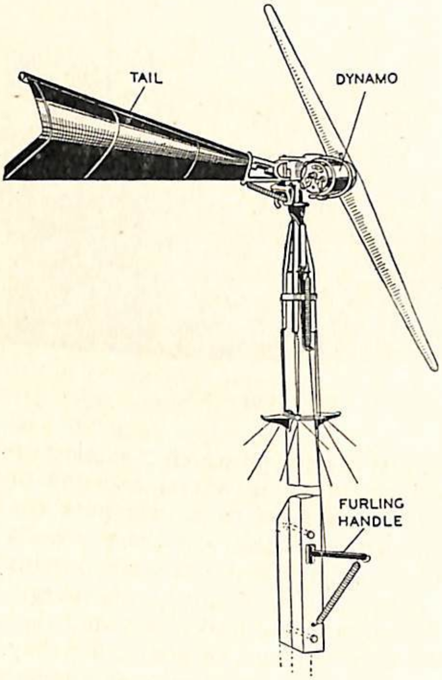


Fig. 117. A Lucas "Freelite" wind-driven generator, comprising a 12-volt dynamo directly coupled to a twin-bladed propeller mounted on a mast.

Wind - driven generators are usually of small size unless the site is well up on a hillside. The dynamo is often mounted on the top of a steel tower, and the dynamo shaft carries a large-diameter wind wheel or propeller. For lighting the outbuildings of a farm such appliances are valuable because they cost practically nothing to operate. So long as the dynamo bearings are lubricated and the battery acid level checked at intervals, no further attention is required. The whole apparatus can be made from odd scraps of metal and a car dynamo. The only "gadget" necessary to fit is an automatic cut-out to prevent the battery current passing back into the dynamo when no wind is blowing. This cut-out is described in the tractor-lighting section.

Regarding the installation of water turbines, it may be of interest to point out that specialist firms of turbine manufacturers are thoroughly familiar with most of the rivers and streams in Britain.

Local water-power schemes are—with certain exceptions—auxiliaries to oil-engine power, and can be exploited to the utmost where favourable conditions exist.

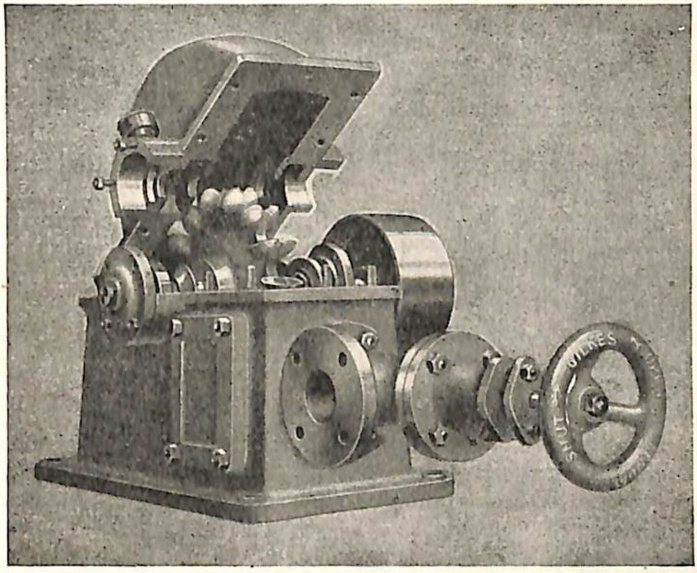


Fig. 118. A Pelton wheel impulse turbine with cover lifted to show the shape of the buckets. A circular jet of water strikes these buckets causing the wheel to rotate and transmit power.

Nevertheless, water turbines are cheaper than engines, although this is offset by the cost of the civil engineering works which may be necessary. In a few cases there may be sufficient water available all the year round for the operation of a small or moderate-sized turbine without a dam. More generally, seasonal drying up or reduced flow will mean a power shortage in summer. But even this can be overcome. A water turbine can be installed in conjunction with an existing or projected oil-engine set, the latter operating in summer and both sharing the heavier winter load. In this way various local power sources may gradually be exploited and arranged to help each other when circumstances demand it.

There are two main types of water turbines: (1) Reaction turbines suitable for low and medium falls, up to, say, 300 ft. (although more can be accommodated); and (2) impulse turbines of the Pelton Wheel type, suitable for falls of 100 ft. and more and for use with advantage on falls as low as 30 ft., if a small amount of power is required.

Fault-finding in Electrical Installations

Turning now to electrical fault-finding, it is, in theory at any rate, quite simple, because it merely means locating a break in the circuit. The trouble lies in finding the exact spot, and the only way to do this is to proceed with a definite order of tests. One must remember that a break in a circuit does not necessarily mean a broken wire, for dirt and corrosion and a loose terminal or joint will have the same effect.

Because there is such an enormous number of different electrical circuits, it is not possible to go into testing methods completely. It is not, as a rule, difficult to trace a fault, even if one has little or no testing apparatus.

One illustration of the method will suffice as a guide, and we will suppose that the switching on of a lamp in a house-wiring system produces no light. The fault may be due to a mains supply failure ; so if other lamps in different parts of the house are switched on, one soon finds out. Assuming that the mains supply is all right, the best thing to do is to check back along the defective circuit, beginning at the lamp.

Insert another lamp which is known to be good, and switch on again. If this lamp does not light, inspect the fuse. If this is sound, then the fault lies either between the main switchboard and the fuse, or between the switch and the lamp, and this includes the wire to the ceiling rose from the switch ; the wire from the rose to the lampholder, and, of course, the lampholder and switch. One very useful piece of test apparatus is a lamp and holder and a length of twin flex such as is shown in Fig. 119. It is desirable to have some form of handle for each of the wires, and these can be made by placing a strip of wood about 6 ins. long against each wire, leaving half an inch or so of bare wire projecting. Bind the wood to the wire with insulating tape.

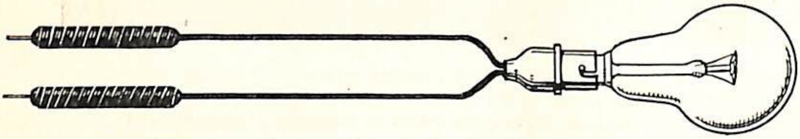


Fig. 119. A test lamp with leads for checking electrical faults.

Such a tester can be used to find if the current is reaching any section of the installation. For instance, should the fuse be sound, touch the mains side of the fuse terminals with the test prongs, taking care not to short the circuit. If the lamp lights, then the current is reaching the fuse. Check the other side of the fuse with the lamp in case there is a break in the fuse wire which cannot be seen. If this lights, then the fault must lie between the fuse and the lamp. The lamp has already been tested, because this is the most likely cause of trouble, and as such should be the first to be looked at. The tester is next taken to the ceiling rose. If the tests are made in this manner, it is not long before the actual section of wire that is at fault is discovered.

There are instruments which enable one to locate the actual spot in the wiring, but it is unlikely that the farmer will have one of them. When a break is discovered switch off the mains before attempting to effect a repair, otherwise trouble will arise. Do not merely twist wires together, but clean and solder them binding the join with insulating tape after removing any surplus flux. Loose connections should be cleaned before being tightened.

A most useful testing device which has great adaptability is the Runbaken Testoscope. It costs but a few shillings, but it is almost indispensable where electrical apparatus is used. The Testoscope will test sparking plugs, magnetos, dynamos, motors, electric wiring and even radio sets.

XXXIII

STORAGE OF COMBINE HARVESTERS

GOOD storage and repairs carried out at the proper time are indispensable to the owner of a combine harvester. Repairs should be carried out at once after a machine has finished its season's work when the operator will know what small defects have developed, and if all the spare parts required are not obtainable straight away, the agent will have plenty of time to obtain them before the machine is wanted again.

When preparing the machine for storage, it should be run until all grain and dust are out of it. Next remove all bolts and chains, hang belts preferably in a cool, dark place, and immerse chains (after examination for worn links that may need renewing) in a bucket of oil. Then remove the canvases and have any necessary repairs done. Treat the straps with harness oil to keep them soft and pliable, and put a little oil on the buckles to prevent rusting. Hang the canvases in a dry place out of reach of vermin.

Disconnect the pitman (connecting-rod), and check it for wear in the bearings. Withdraw the knife and look for wear in the eye and for loose or worn sections or damaged ledger plates. Removal of the reel assembly is optional, but arms and beaters often need replacing or repair after a season's work. Elevator chains are easy to inspect and repair when removed, but should not be put in oil. The danger of corn growing at the bottom of the elevator casings and damaging the sheet metal is easily prevented by leaving the inspection covers off.

After removing any short pieces of straw which may have accumulated in the shakers and thoroughly cleaning the sieves (taking them out if necessary), the beaters, where the largest accumulation of dirt is usually found, should be cleaned. Then the machine should be washed down outside, using paraffin and a brush where necessary to remove grease, and all dust swept from the inside. The combine is now ready to inspect, and, being washed, its faults and defects are easier to locate.

Wear on Bearings

Each shaft may now be turned independently to test for wear on bearings or sideplay. Sideplay on shafts is often caused by wear: on those which carry jockeys for tightening belts and chains most wear is found in the bush. All nuts need to be checked and tightened if necessary. Particular attention should be given to ball races and roller bearings, the seals of which must be in good condition if they are to prevent dust from entering the bearings. Undue wear is often caused on rollers and their bearings by the canvases being run too tight. Augers often need slight welding repairs, and cannot be properly inspected unless removed. All pulleys and sprocket, should be firm on their shafts. Shaker bearings need little attention but should be inspected before storage.

Perhaps the most important parts of the combine harvester are the beaters and concave. Unless they are in good condition, good threshing is impossible, and grain will be left in the straw. Combines which have done a few seasons' work need particular attention at this point, as much wear may have taken place. No specified period can be given as to when repairs and replacements will be needed, as everything depends on working conditions. Severe damage may occur in a single season if stones or other hard objects pass through the machine, as often happens when using a pick-up. Beater plates can usually be fitted quite easily without removing the drum, but the balance should be checked afterwards. For repairs to the concave, the latter must be taken out of the machine.

Concaves vary in type, and the agent is the best man to carry out repairs. Solid-bar types can be planed and rewired. Inspect your concave and beaters each year, and if in doubt, ask the advice of an expert. The cost of regular maintenance or repairs to these parts will be more than repaid by the extra grain and in ease of threshing.

Precautions Against Corrosion

Many of the early combines were made of rustless sheeting and were not damaged by bad weather. Most machines are now of a different material which is painted. When the paint wears off either inside or outside rust will form quickly, especially when the machine is idle. In time rust will eat through the sheeting and make holes which can cause much lost grain when threshing. A coat of good-quality anti-corrosive paint is the best preventive, and should be put on before storing the machine. When repairs have been carried out bright parts should be given a covering with thick grease or rust preventive.

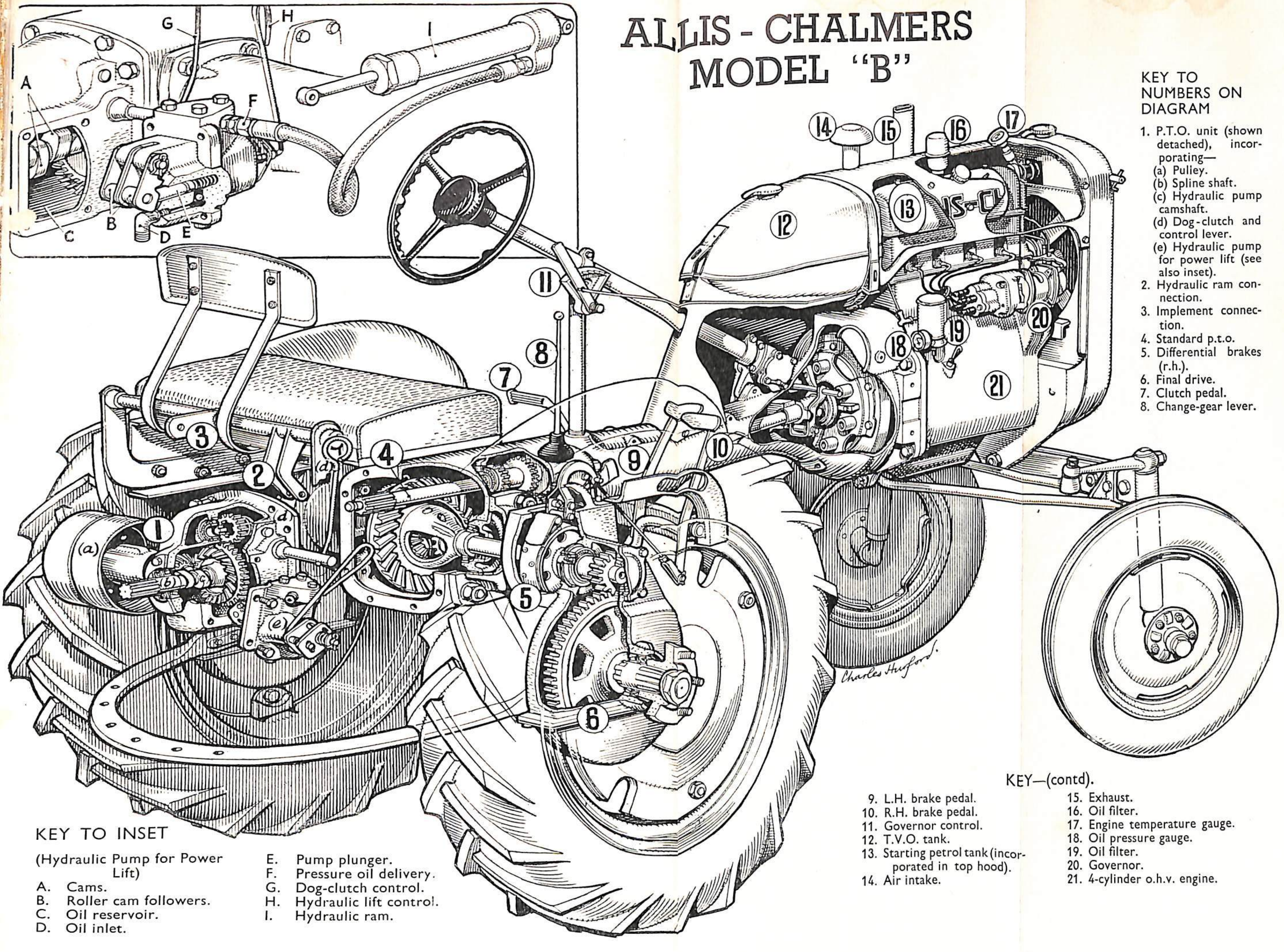
In self-propelled combines or trailer types with a mounted engine, the engine calls for special attention. Much depends on the amount of work it has done and the working conditions as to whether it needs decarbonizing or possibly a major overhaul. In any case, several minor jobs will need doing. The air cleaner should be totally dismantled, every screen removed and thoroughly washed in paraffin and all dust removed from the intake pipe. The radiator and cooling system should be drained and the oil drained from the engine sump and replenished with new oil.

After the sparking plugs have been removed, a little oil should be poured into each cylinder, after which the engine needs turning a few times so as to leave a film of good oil on the cylinder walls to prevent rusting. All fuel lines and strainers must be cleaned, and if fuel tanks are not emptied, filling to within half an inch of the top will prevent condensation.

The magneto needs special care, and is best removed and stored in a warm place. If left on the engine it should at least be covered with some dry sacking and waterproof covering. The battery (on engines with self-starters and coil ignition) should be removed and taken to a service station to be emptied : the plates would be damaged in a battery standing idle a long time.

The next problem on many farms is to find a shed big enough to accommodate the combine, for even a small machine needs quite a lot of room. If a shed is not high enough, this difficulty can often be overcome by removing grain tanks and elevators. If the opening to the shed is not wide enough, taking off the cutterbar may be the answer. A shed can be built very cheaply with baled straw, and this avoids robbing the very limited storage space on most farms. In any case, put the machine under cover, jack the wheels off the ground if fitted with rubber tyres, and cover them with sacks ; this method keeps the rubber soft and pliable. Finally, cover with a cloth and try not to let fowls roost on the combine for about ten months of the year.

ALLIS - CHALMERS MODEL "B"



KEY TO NUMBERS ON DIAGRAM

1. P.T.O. unit (shown detached), incorporating—
   - (a) Pulley.
   - (b) Spline shaft.
   - (c) Hydraulic pump camshaft.
   - (d) Dog-clutch and control lever.
   - (e) Hydraulic pump for power lift (see also inset).
2. Hydraulic ram connection.
3. Implement connection.
4. Standard p.t.o.
5. Differential brakes (r.h.).
6. Final drive.
7. Clutch pedal.
8. Change-gear lever.

KEY—(contd).

9. L.H. brake pedal.
10. R.H. brake pedal.
11. Governor control.
12. T.V.O. tank.
13. Starting petrol tank (incorporated in top hood).
14. Air intake.
15. Exhaust.
16. Oil filter.
17. Engine temperature gauge.
18. Oil pressure gauge.
19. Oil filter.
20. Governor.
21. 4-cylinder o.h.v. engine.

KEY TO INSET

(Hydraulic Pump for Power Lift)

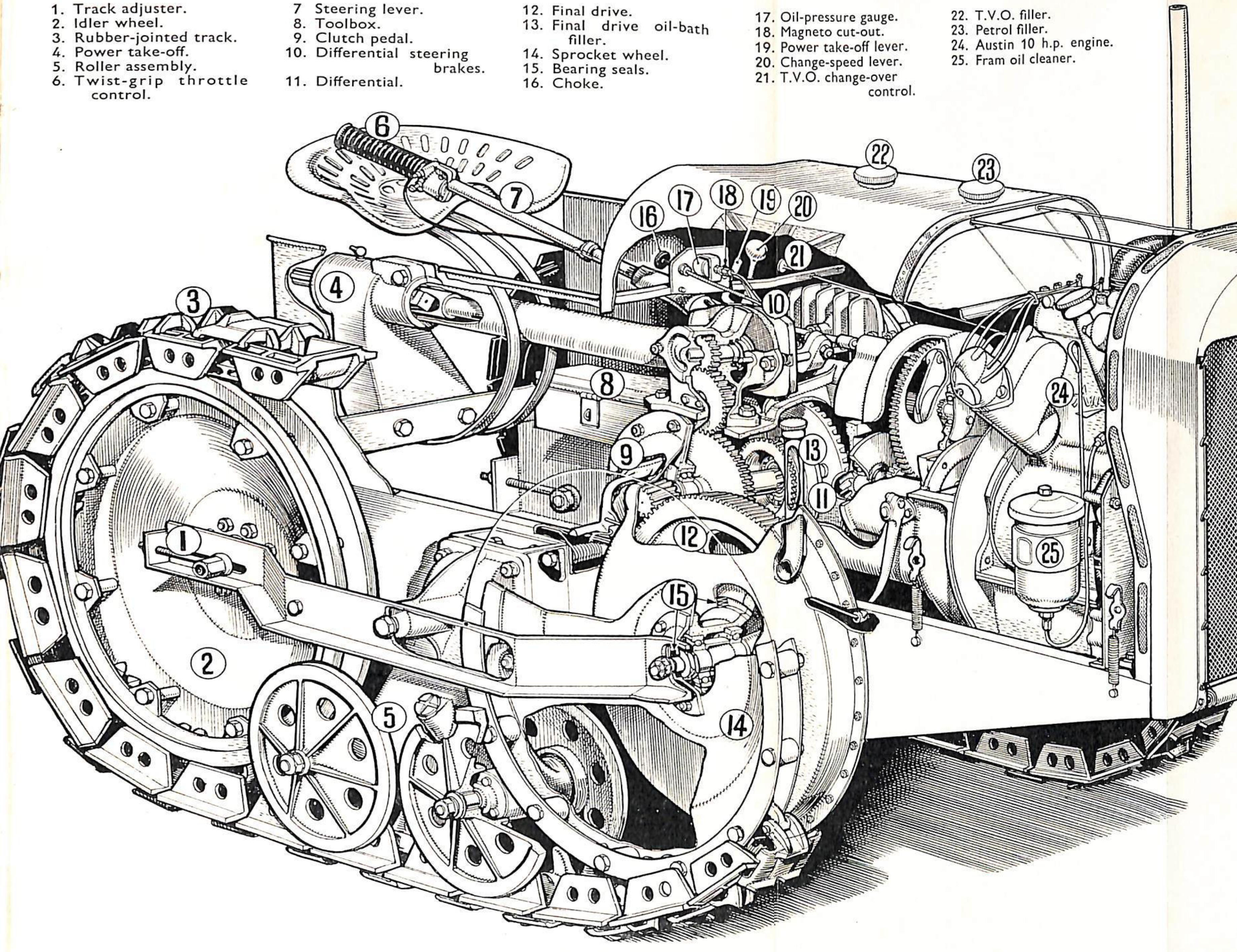
A. Cams.
B. Roller cam followers.
C. Oil reservoir.
D. Oil inlet.
E. Pump plunger.
F. Pressure oil delivery.
G. Dog-clutch control.
H. Hydraulic lift control.
I. Hydraulic ram.

THE BRISTOL TRACTOR

T.V.O. Model with Wide Tracks

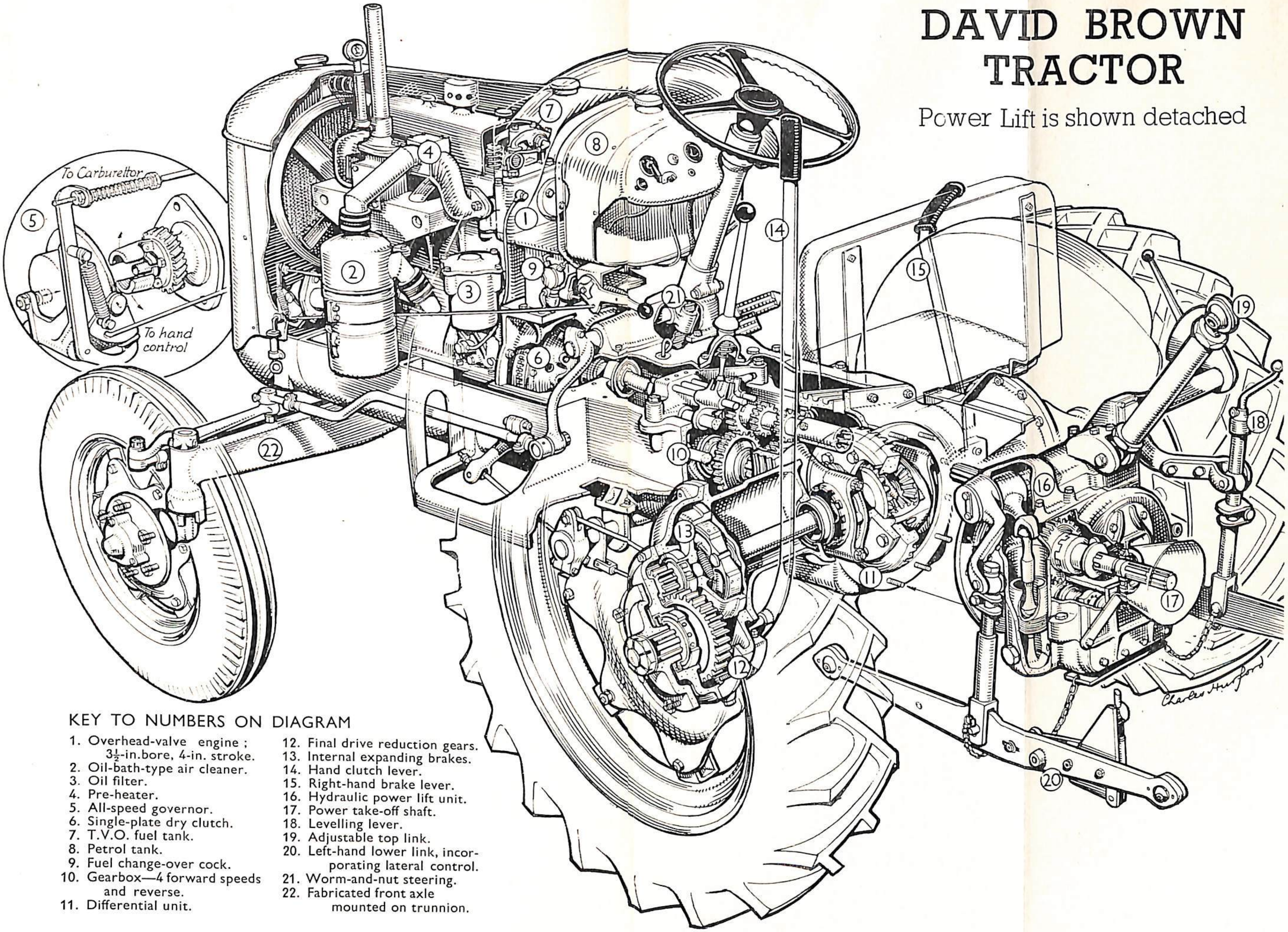
KEY TO NUMBERS ON DIAGRAM

1. Track adjuster.
2. Idler wheel.
3. Rubber-jointed track.
4. Power take-off.
5. Roller assembly.
6. Twist-grip throttle control.
7. Steering lever.
8. Toolbox.
9. Clutch pedal.
10. Differential steering brakes.
11. Differential.
12. Final drive.
13. Final drive oil-bath filler.
14. Sprocket wheel.
15. Bearing seals.
16. Choke.
17. Oil-pressure gauge.
18. Magneto cut-out.
19. Power take-off lever.
20. Change-speed lever.
21. T.V.O. change-over control.
22. T.V.O. filler.
23. Petrol filler.
24. Austin 10 h.p. engine.
25. Fram oil cleaner.



DAVID BROWN TRACTOR

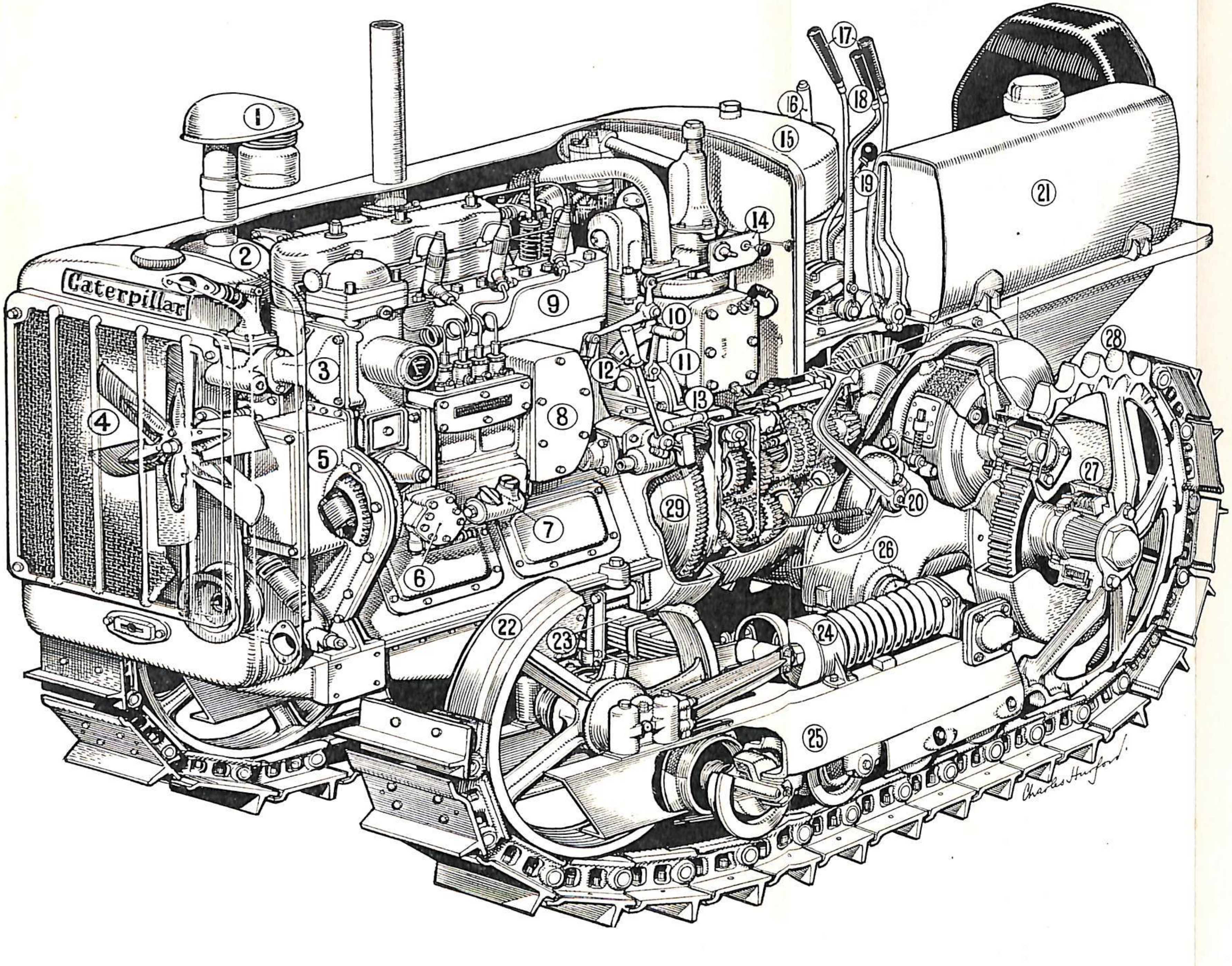
Power Lift is shown detached



KEY TO NUMBERS ON DIAGRAM

1. Overhead-valve engine ; 3½-in. bore, 4-in. stroke.
2. Oil-bath-type air cleaner.
3. Oil filter.
4. Pre-heater.
5. All-speed governor.
6. Single-plate dry clutch.
7. T.V.O. fuel tank.
8. Petrol tank.
9. Fuel change-over cock.
10. Gearbox—4 forward speeds and reverse.
11. Differential unit.
12. Final drive reduction gears.
13. Internal expanding brakes.
14. Hand clutch lever.
15. Right-hand brake lever.
16. Hydraulic power lift unit.
17. Power take-off shaft.
18. Levelling lever.
19. Adjustable top link.
20. Left-hand lower link, incorporating lateral control.
21. Worm-and-nut steering.
22. Fabricated front axle mounted on trunnion.

CATERPILLAR D2 TRACTOR



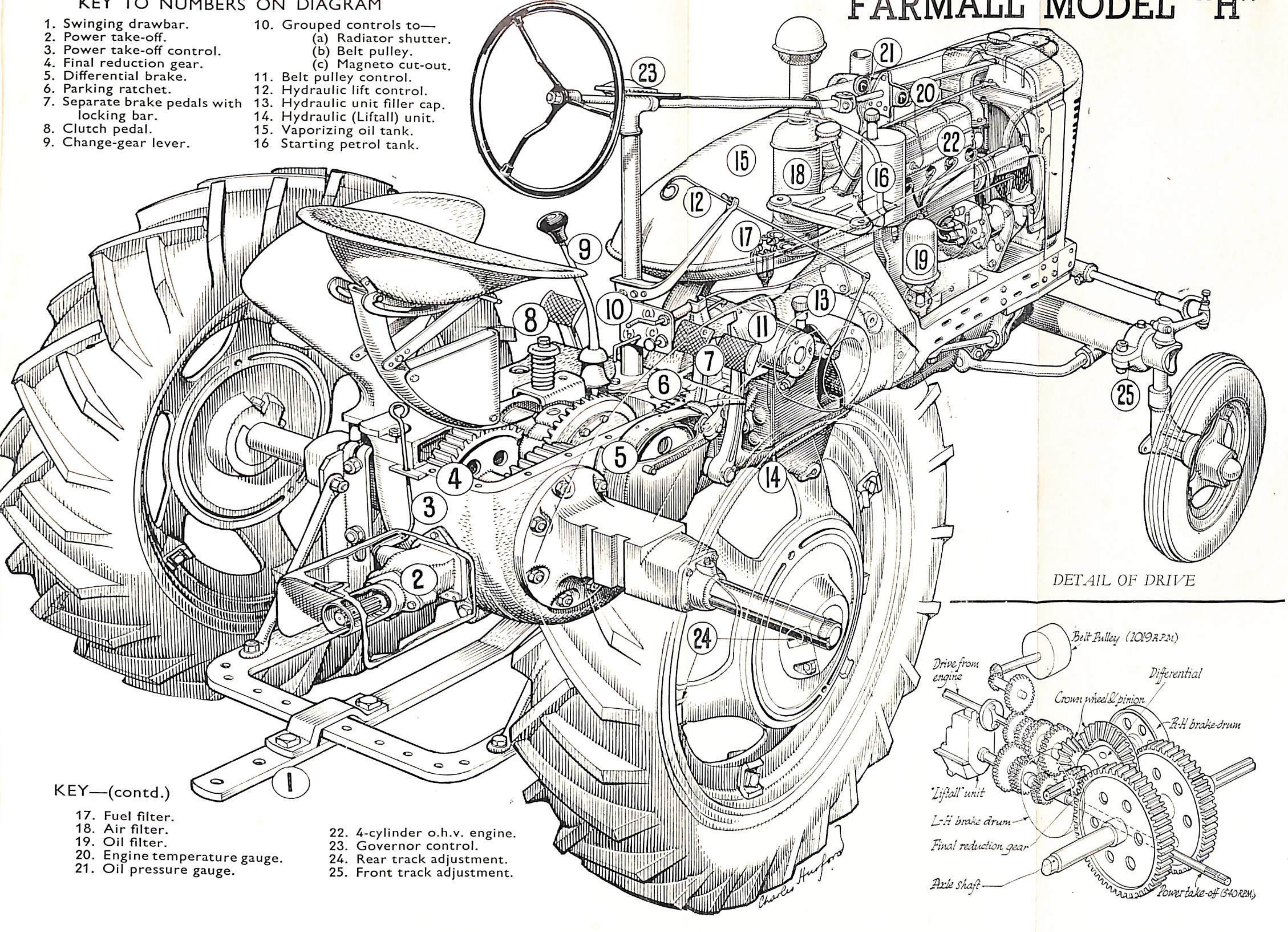
KEY TO NUMBERS ON DIAGRAM

1. Air pre-cleaner.
2. Main air cleaner.
3. Water-heated fuel filter.
4. Oil cooler.
5. Engine governor.
6. Fuel transfer pump.
7. Hour meter.
8. Fuel pump governor.
9. 4-cylinder o.h.v. Diesel engine.
10. Decompressor.
11. Starting engine.
12. Starting clutch control.
13. Starting pinion lever.
14. Starting engine controls.
15. Starting engine fuel tank.
16. Governor control.
17. Steering clutch levers.
18. Main clutch control.
19. Change-gear lever.
20. Steering-clutch brake (l.h.)
21. Fuel tank.
22. Front idler.
23. Equalizer spring.
24. Idler recoil spring.
25. Track roller frame.
26. Pivot shaft.
27. Sprocket bearing seal
28. Driving sprocket.
29. Engine flywheel.

FARMALL MODEL "H"

KEY TO NUMBERS ON DIAGRAM

1. Swinging drawbar.
2. Power take-off.
3. Power take-off control.
4. Final reduction gear.
5. Differential brake.
6. Parking ratchet.
7. Separate brake pedals with locking bar.
8. Clutch pedal.
9. Change-gear lever.
10. Grouped controls to—
    (a) Radiator shutter.
    (b) Belt pulley.
    (c) Magneto cut-out.
11. Belt pulley control.
12. Hydraulic lift control.
13. Hydraulic unit filler cap.
14. Hydraulic (Liftall) unit.
15. Vaporizing oil tank.
16. Starting petrol tank.



DETAIL OF DRIVE

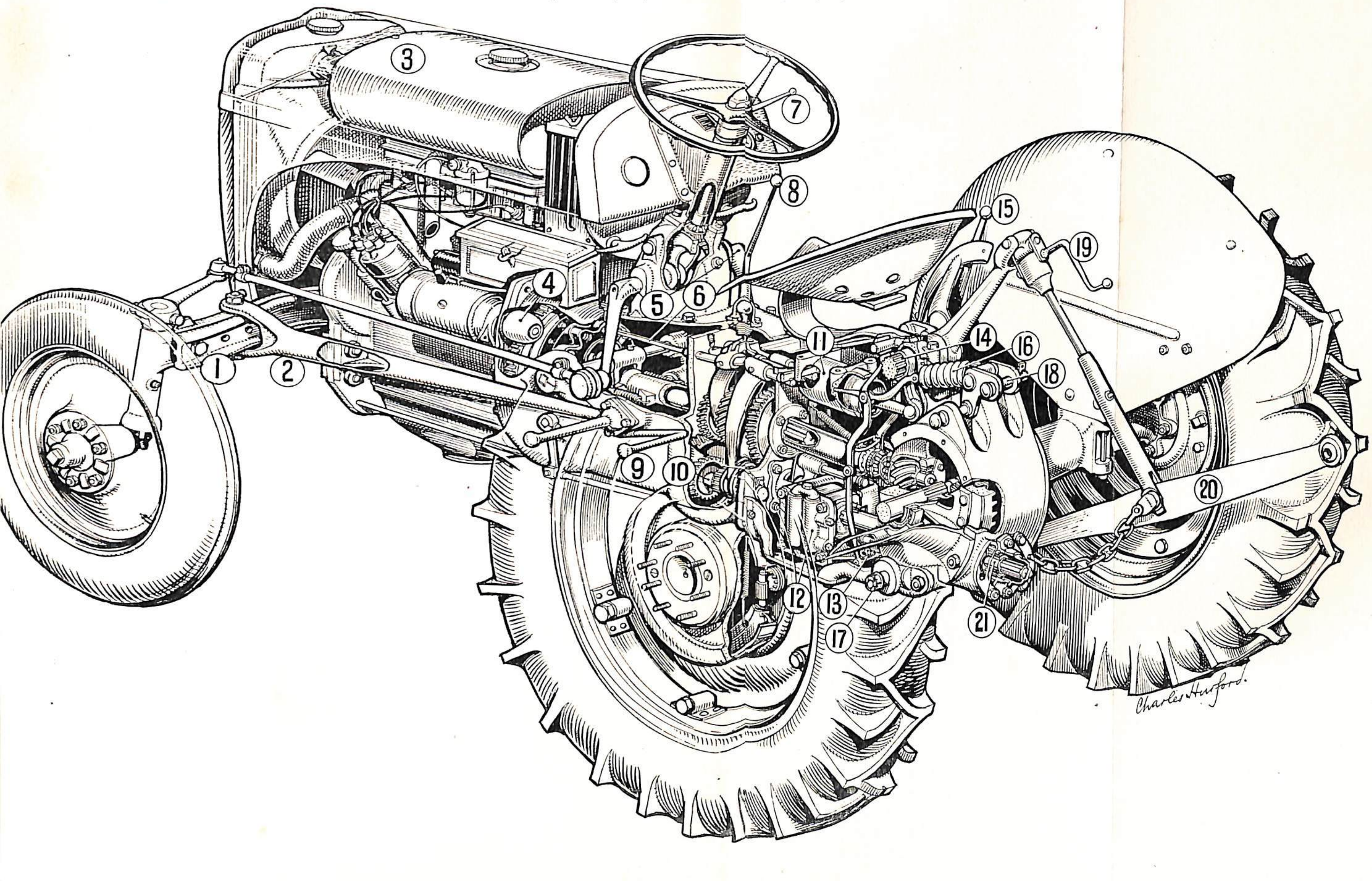
KEY—(contd.)

17. Fuel filter.
18. Air filter.
19. Oil filter.
20. Engine temperature gauge.
21. Oil pressure gauge.
22. 4-cylinder o.h.v. engine.
23. Governor control.
24. Rear track adjustment.
25. Front track adjustment.

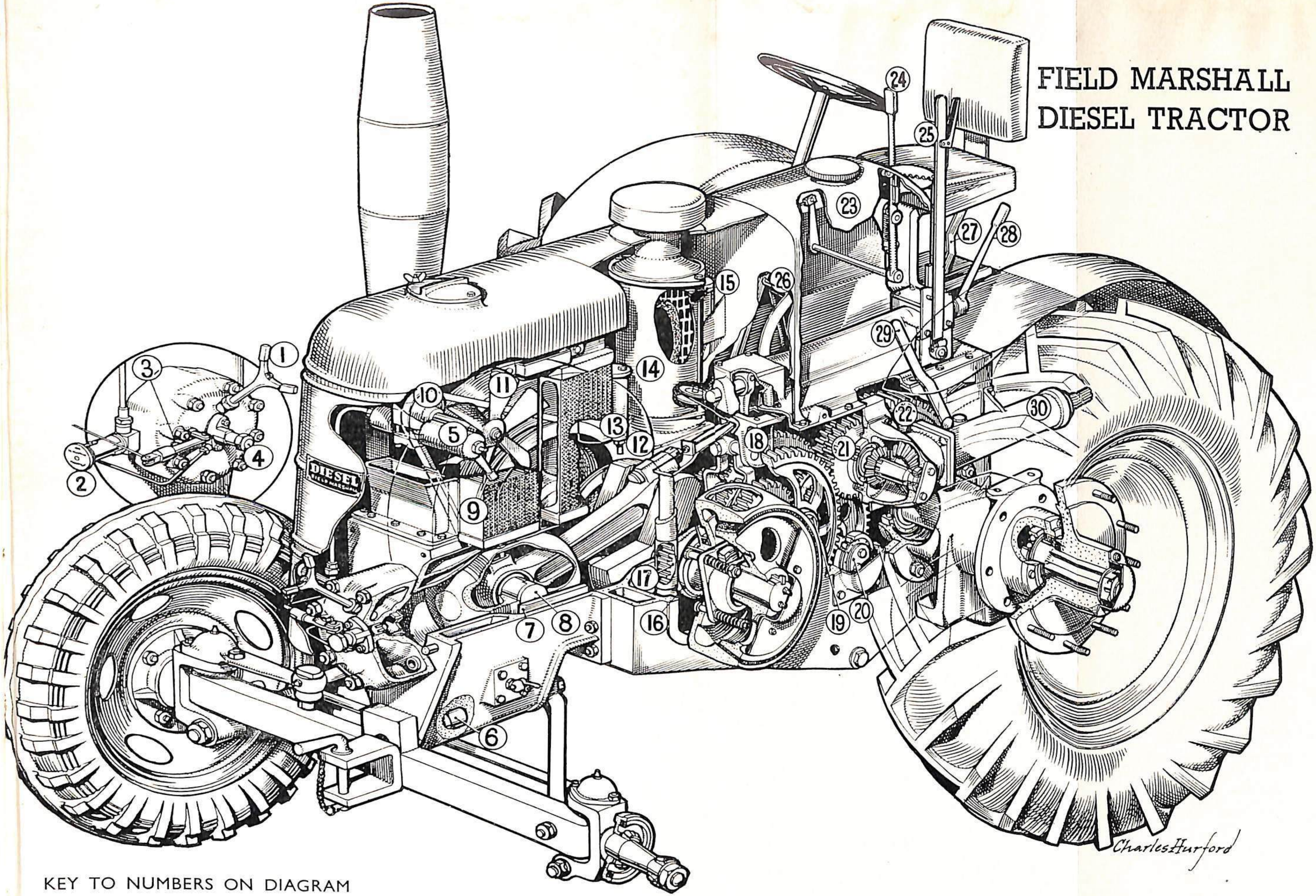
THE FERGUSON TRACTOR

KEY TO NUMBERS ON DIAGRAM

1. Front track adjustment.
2. Radius arm.
3. Petrol tank.
4. Electric starter.
5. Twin steering drop arms.
6. Starter switch linkage.
7. Governor control.
8. Change-gear lever.
9. Clutch pedal.
10. Reverse gear layshaft.
11. Hydraulic ram unit.
12. Hydraulic pump unit.
13. Control valve.
14. Hydraulic lift shaft.
15. Finger-tip hydraulic control.
16. Control spring.
17. L.H. tension link connection.
18. Compression link connection.
19. Levelling lever.
20. R.H. tension link.
21. Gearbox layshaft extension driving hydraulic pump and p.t.o.



FIELD MARSHALL DIESEL TRACTOR



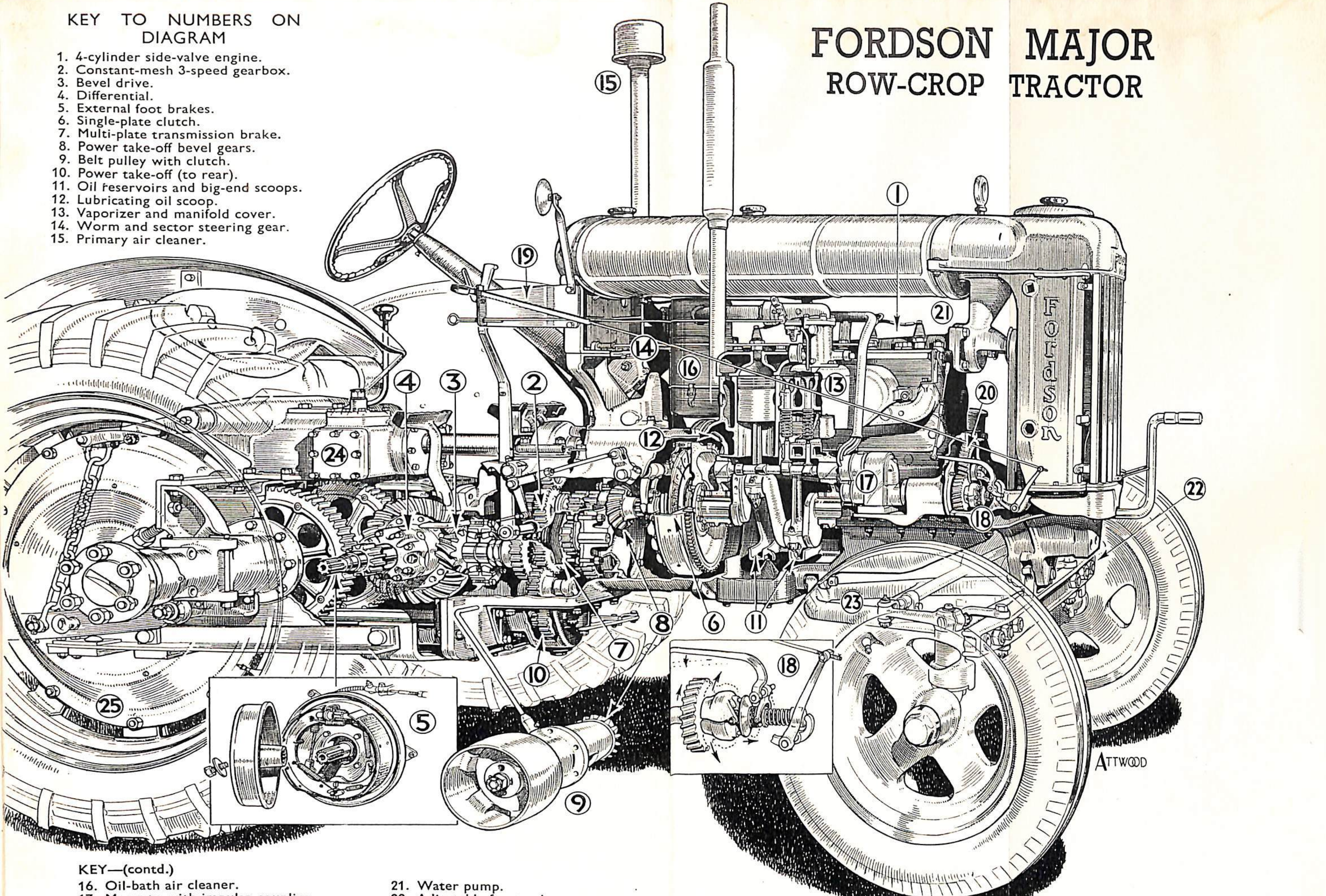
KEY TO NUMBERS ON DIAGRAM

1. Ignition paper holder.
2. Hand-start valve.
3. Compression release valve.
4. Fuel injector.
5. Cartridge starter.
6. Front axle pin.
7. Transfer port.
8. Piston pad.
9. Radiator.
10. Fan drive.
11. Fan.
12. Flywheel.
13. Oil filter.
14. Air cleaner.
15. Fuel filter.
16. Clutch operating fork.
17. Crankshaft pinion.
18. Gear selectors.
19. First motion shaft.
20. Second motion shaft.
21. Power take-off drive.
22. Differential and final gear.
23. Fuel tank.
24. Fuel control.
25. Brake.
26. Clutch foot control.
27. Clutch hand control.
28. Change-gear lever.
29. P.T.O. control.
30. P.T.O. unit.

FORDSON MAJOR
ROW-CROP TRACTOR

KEY TO NUMBERS ON DIAGRAM

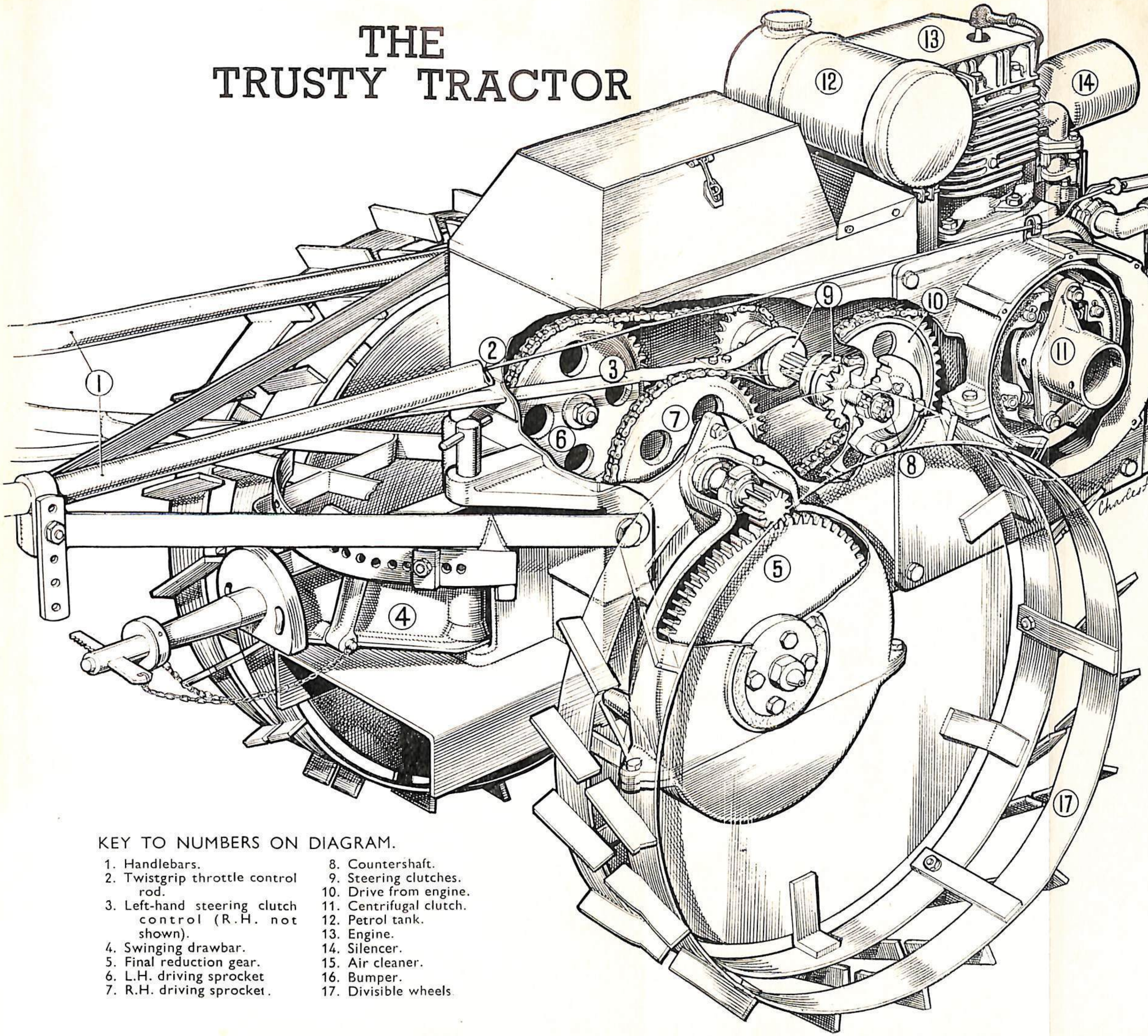
1. 4-cylinder side-valve engine.
2. Constant-mesh 3-speed gearbox.
3. Bevel drive.
4. Differential.
5. External foot brakes.
6. Single-plate clutch.
7. Multi-plate transmission brake.
8. Power take-off bevel gears.
9. Belt pulley with clutch.
10. Power take-off (to rear).
11. Oil reservoirs and big-end scoops.
12. Lubricating oil scoop.
13. Vaporizer and manifold cover.
14. Worm and sector steering gear.
15. Primary air cleaner.



KEY—(contd.)

16. Oil-bath air cleaner.
17. Magneto with impulse coupling.
18. Governor.
19. Governor control.
20. Camshaft gear.
21. Water pump.
22. Adjustable front axle.
23. Radius rods.
24. Hydraulic power lift.
25. Adjustable wheel disc and rim.

THE TRUSTY TRACTOR



KEY TO NUMBERS ON DIAGRAM.

1. Handlebars.
2. Twistgrip throttle control rod.
3. Left-hand steering clutch control (R.H. not shown).
4. Swinging drawbar.
5. Final reduction gear.
6. L.H. driving sprocket
7. R.H. driving sprocket.
8. Countershaft.
9. Steering clutches.
10. Drive from engine.
11. Centrifugal clutch.
12. Petrol tank.
13. Engine.
14. Silencer.
15. Air cleaner.
16. Bumper.
17. Divisible wheels.

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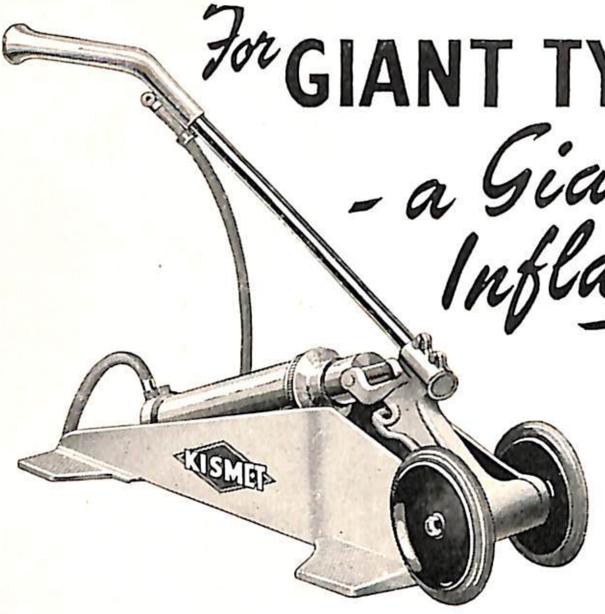

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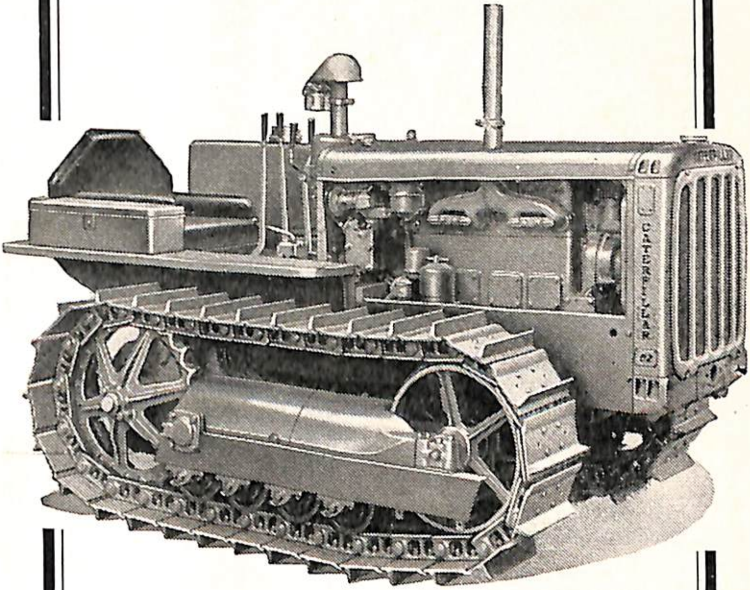

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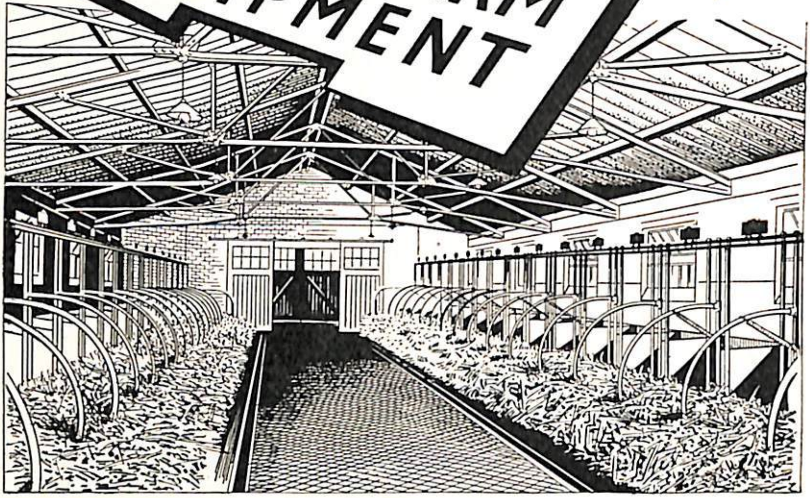

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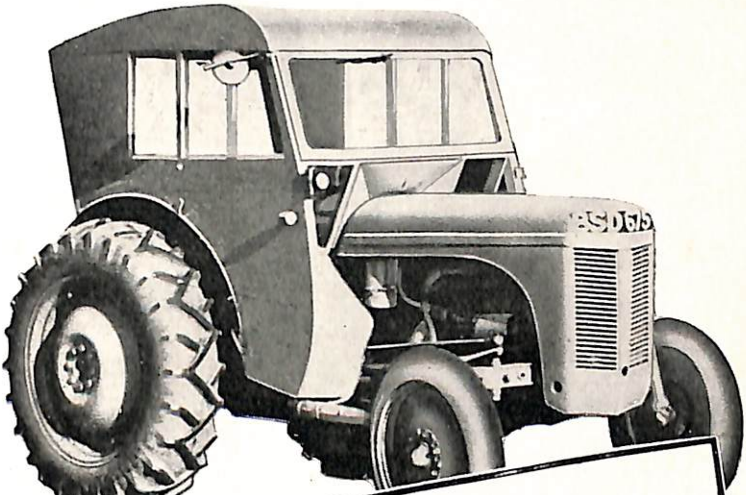

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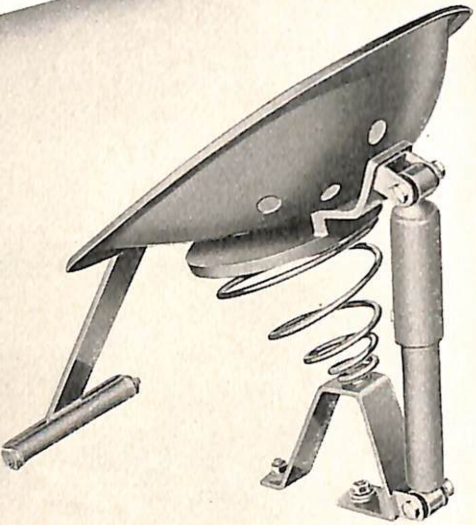

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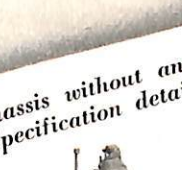

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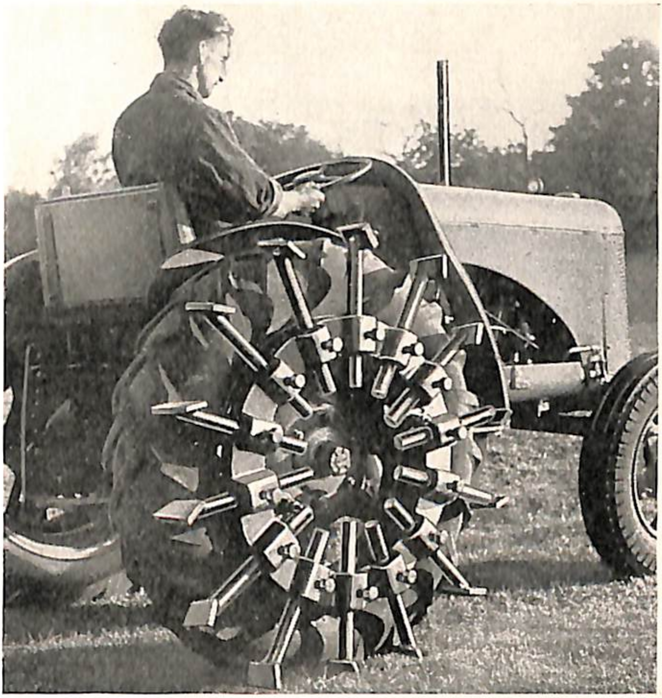

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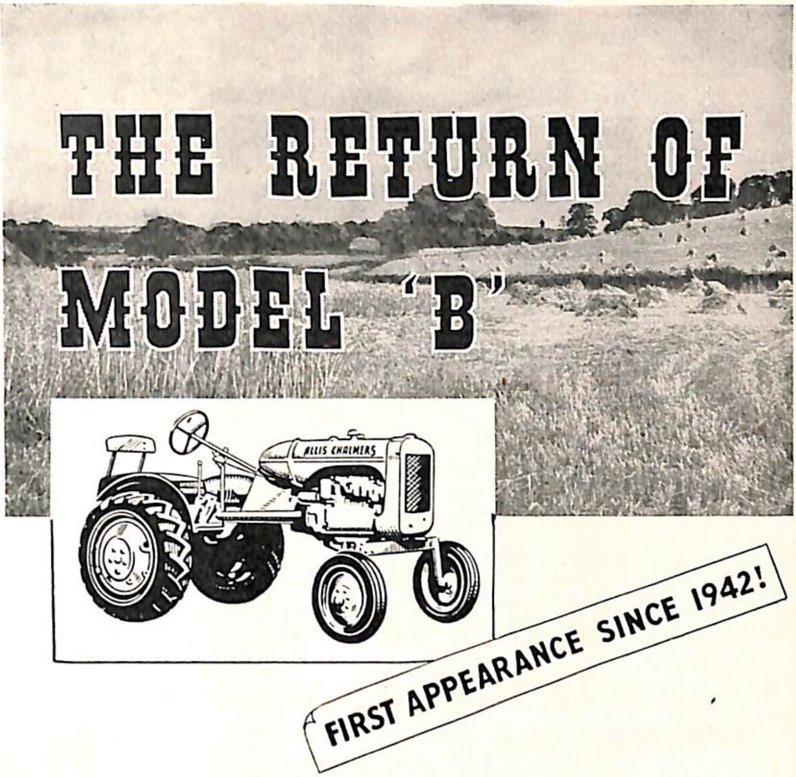

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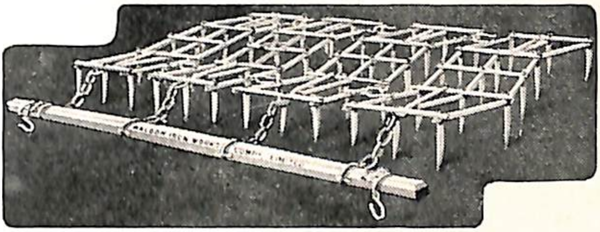

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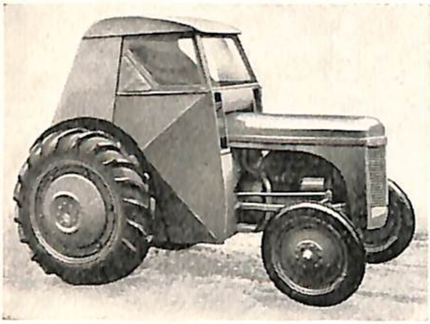

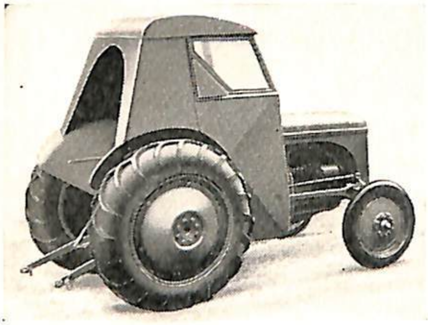

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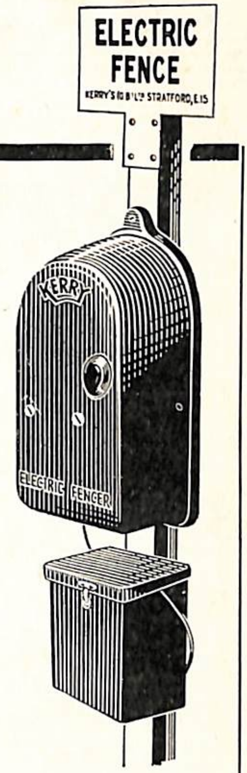

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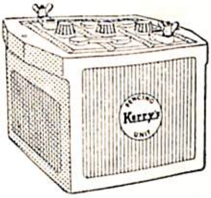

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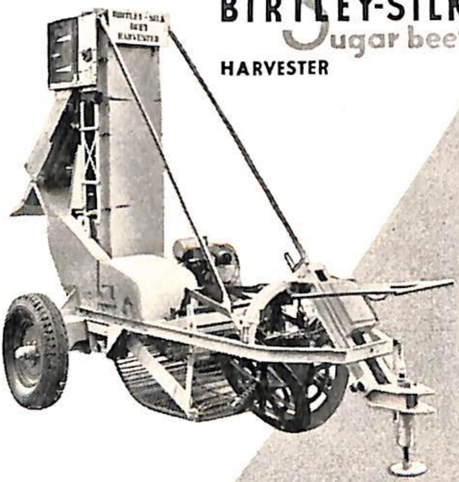

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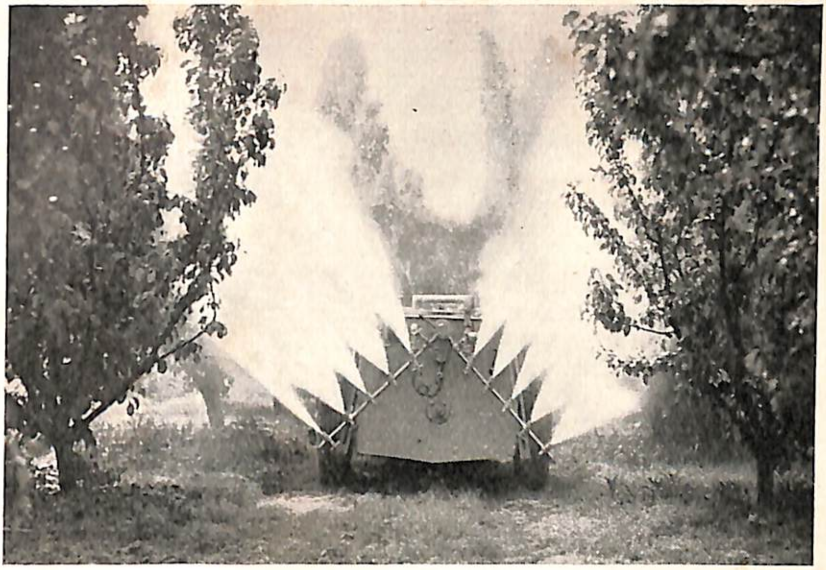

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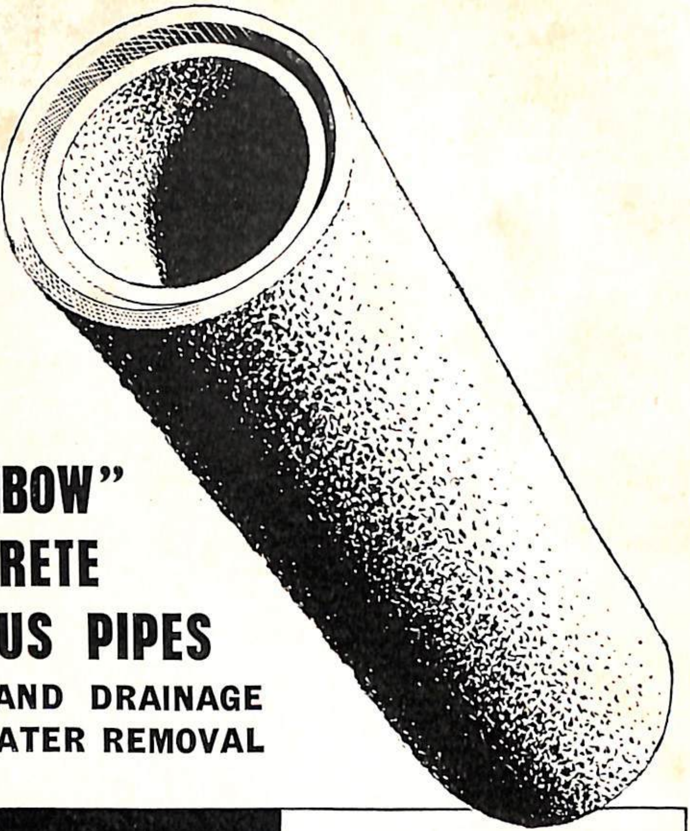

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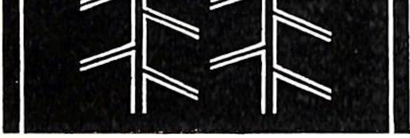

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